Critical Evaluation of Methods and Outcomes for Habitat/Ecological Systems Classification and Mapping in the Northeast and Midwest U.S.

Final Report

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Introduction

A number of large-scale mapping projects have been completed in the U.S., and several cover all or some parts of the footprint of the Northeast Climate Science Center (NECSC; Figure 21). These include maps by the Southeast GAP Analysis (SEGAP) program (Jennings et al. 1993, Kleiner 2007), the national LANDFIRE program (Rollins et al. 2006, Rollins 2009), NatureServe (Comer et al. 2003, NatureServe 2009, Smyth et al. 2013), and The Nature Conservancy (Ferree and Anderson 2013). These mapping projects represent a major step forward in describing the current extent of ecosystems on the landscape, and provide resource management agencies and organizations with unprecedented access to spatial information on these systems.

In a number of cases, the ranges of these maps overlap. As a result, staff of resource management agencies and organizations are faced with trying to determine how to use these multiple products to effectively and efficiently meet their needs. To address this question in the northeast and Midwest U.S., the Northeast Climate Science Center (NECSC) funded a project to critically evaluate these ecosystem or habitat mapping methods and to move toward standardization of these maps. The objectives of the project were to:

> Phase1: Review and compare existing map products
> Phase II: Extend the map legends & identify legend elements (ecosystems) most vulnerable to climate change
> Phase III: Develop recommendations for an improved map for the region
> Phase IV: Produce an improved regional map

The four map products that span all or large parts of this area (as shown in Figure 1) include):

1. Southeast GAP (SEGAP)
2. LANDFIRE EVT (Existing Vegetation Type)
3. NatureServe
4. TNC

To facilitate flow in this document, results from Phase I, III, and IV are presented in that order, followed by Phase II results.

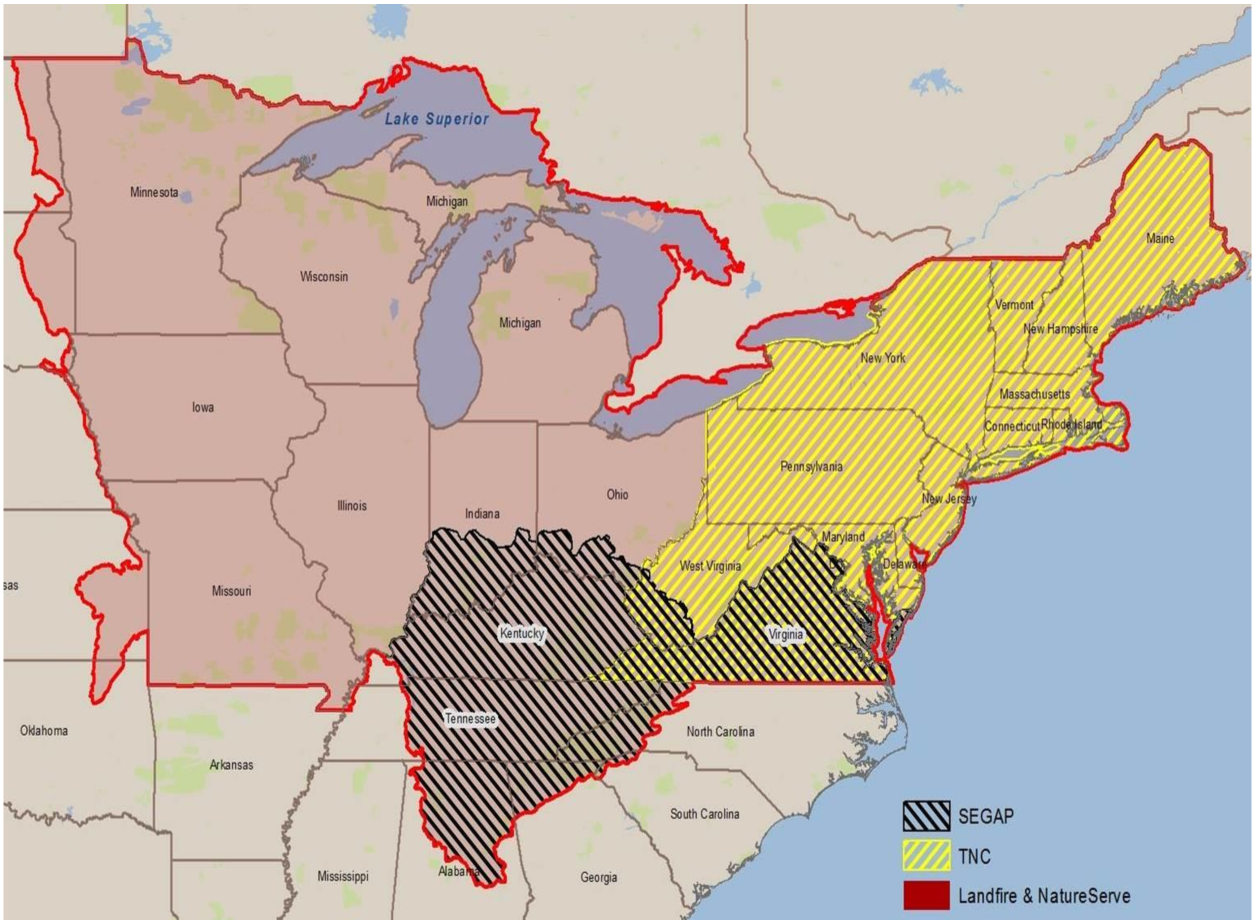

Figure 1. Extent of analysis showing the area of overlap for each of the four compared map products. LANDFIRE and NatureServe maps provide coverage of the contiguous lower 48 states, and the Southeast GAP map extends south to cover additional area outside the NECSC project.

Of these, SEGAP and LANDFIRE began the mapping process with raw remote sensing data, whereas NatureServe and TNC did not (see Input Data and Mapping Methods, below). Major commonalities of these products include:

1) NatureServe's ecological systems classification was used as a starting base for defining map classes for natural land cover (Comer et al. 2003).
2) LANDSAT data from 1999 – 2008 (30 m resolution) was the imagery source for all map producers, although TNC and NatureServe did not analyze raw satellite remote sensing data.
3) The National Land Cover Database (NLCD) was used to supplement the classification and mapping for cultural land cover (see http://www.mrlc.gov/nlcd2006.php).

Phase 1: Review and Compare Existing Maps

Base Classification for Map Legends

Standardized, multi-level classifications of upland and wetland ecosystems and vegetation provide a consistent framework for natural resource conservation, management, and monitoring.

The standardized classification supports characterization and mapping of ecosystem types and wildlife habitats that cross political jurisdictions. As noted above, all of the mapping projects reviewed here share a commitment to using the NatureServe Ecological Systems classification as their primary classification source, supplemented with the US National Vegetation Classification (USNVC). These two classifications are coordinated, because Systems are already linked, and largely nest within, mid-levels of the USNVC, usually at the macrogroup level. But Systems only cover natural or native vegetation, so ruderal (or semi-natural) vegetation and cultural vegetation are not completely addressed. The USNVC had developed units these vegetation types in finer detail than were available at the time of production of these maps (FGDC 2008). Cultural (agricultural and developed) vegetation were largely addressed by map producers by use of results from the NLCD. For ruderal and successional vegetation, map producers typically developed a variety of *ad hoc* types or used preliminary USNVC draft types.

Ecological Systems and USNVC

Terrestrial ecological systems are defined as a single level mid-to-local scale ecological unit useful for standardized mapping and conservation assessments of native ecosystems. Each ecological system type describes complexes of native plant communities influenced by similar physical environments and dynamic ecological processes (like fire or flooding). The classification defines some 600 natural system units across the Temperate North America (primarily the United States, plus adjacent areas in Canada and Mexico) and has provided an effective means of mapping ecological concepts at regional/national scales in greater detail than was previously possible. Type descriptions are found through queries of NatureServe Explorer (see www.natureserve.org).

The USNVC provides a secondary classification that supplements the use of Ecological Systems. The USNVC is a national multi-scale framework to classify and describe all existing vegetation types, including cultural (agricultural fields, lawns etc.), ruderal (e.g., exotic invasive grasslands and forests), and native ecosystems. The USNVC was developed under the auspices of the U.S. Federal Geographic Data Committee (FGDC; www.fdgc.gov), which is an interagency committee that promotes the coordinated development, use, sharing, and dissemination of geospatial data on a national basis. The FGDC Vegetation Subcommittee has members that include federal agencies and non-federal partners (NatureServe and the Ecological Society of America's Panel on Vegetation Classification), who worked together to produce a revised standard for the USNVC (FGDC 2008), based on national and international classification (Jennings et al. 2009; Faber-Langendoen et al. 2009, Faber-Langendoen et al. 2014). The 2008 standard provides an eight-level hierarchy for the USNVC, common terminology, and a dynamic content standard (the classification can be updated with new concepts). By including all vegetation types in a consistent framework, the USNVC can help ecologists address all lands, and track status and trends in vegetation caused by wildfire regimes, insect and disease impacts to vegetation, exotic species invasions, climate change, and development.

Systems and the USNVC can most effectively be used in tandem by linking Systems to the macrogroup level of the USNVC (Table 1). Note that Systems are not strictly hierarchical because they comprise associations that occur in more than one System, and so are not a formal part of the USNVC hierarchy. In scale, Systems are approximately equivalent to either the USNVC Group or Alliance.

Table 1. Ecological Systems and the USNVC. The eight levels of the USNVC hierarchy are shown in relation to Ecological System type for a Midwest prairie fen. Systems link to the USNVC at the Group level, and thereby to the Macrogroup.

USNVC Hierarchy	**NVC Types**
Upper Levels	
Formation Class	Shrub & Herb Vegetation
Formation Subclass	Shrub & Herb Wetland
Formation	Temperate to Polar Bog & Fen
Mid-Levels	
Division	North American Bog & Fen
Macrogroup	North American Boreal & Sub-boreal Alkaline Fen
Group	Northeast and Midwest Prairie Alkaline Fen
Lower Levels	North-Central Interior Shrub-Graminoid Alkaline Fen System
Alliance	Shrubby-cinquefoil / Fine-leaved Sedges Prairie Fen
Association	Shrubby-cinquefoil / Sterile Sedge - Big Bluestem - Indian-plantain Fen

National Land Cover Database

The NLCD serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation. NLCD provides spatial reference and descriptive data for characteristics of the land surface such as thematic class (for example, urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover. NLCD supports a wide variety of Federal, State, local, and nongovernmental applications that seek to assess ecosystem status and health, understand the spatial patterns of biodiversity, predict effects of climate change, and develop land management policy. NLCD products are created by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of Federal agencies led by the U.S. Geological Survey. All NLCD data products are available for download at no charge to the public from the MRLC Web site: http://www.mrlc.gov.

NLCD (2006) uses 16 classes to classify and map the entire nation's land cover (Table 2). The simplicity of the legend ensures consistency across the entire nation. But it also lacks sufficient detail to adequately capture the range of ecosystems across the country. Map producers reviewed here a large number of Ecological Systems for the eight vegetated classes within the NLCD that cover native ecosystems. NLCD retained for use by the four maps reviewed here are the four Developed classes (including open, low, medium, and high intensity), the two Agricultural classes (hay/pasture, cultivated crop), and the two non-vegetated classes.

Table 2. NLCD (2006) class legend organized by general categories.

General Category	NLCD Class
Non-vegetated	Open water
	Perennial ice/snow
Developed	Developed, open space
	Developed, low intensity
	Developed, medium intensity
	Developed, high intensity
Agriculture	Hay/pasture
	Cultivated crops
Natural	Barren land
	Deciduous forest
	Evergreen forest
	Mixed forest
	Shrub/scrub
	Grassland/herbaceous
	Woody wetlands
	Herbaceous wetlands

Creating a Common Legend to Facilitate Comparisons

As described above, all map products used NatureServe Ecological Systems classification as their primary classification source, supplemented with the USNVC and NLCD. However, for a variety of reasons, each map product adapted each of these classifications in slightly different ways. The main reasons for this are as follows:

a. One reason why the map legends differ is that although the map producers all started with the same list of systems, they made different choices when deciding which systems they could map (i.e. the mapping targets), based on their ecological expertise, and the particular mapping method used. These choices are influenced by the natural variability of systems and landscapes, with systems varying in patch size and distinctiveness. For example, small patch types are often hard to map, but some may have distinctive signatures when certain methods are used. As a result, one producer may find that among the 100 systems found in their project area, only 70 are likely to be successfully mapped, whereas two other producers, using slightly different mapping methods, may find they can map 85 of the systems. Producers consider the fact that ecological systems may occur in small to large patches (with small patch systems generally being more difficult to map at the scale the producers were using), some systems lack adequate field samples, and methods differ in their ability to distinguish system occurrences (especially small patch occurrences). Because producers are mapping the same landscape, there will be inherent differences in the maps.

b. Another reason for differing map legends is the choice in how to map systems chosen. Here the issue is whether the systems are mapped individually or in combination, and whether finer subtypes are mapped. The NatureServe map consistently uses systems as the level of classification, but other map producers strategically chose to represent some map classes at coarser or finer thematic resolution. Resolving legends between maps required resolving how the lumps and splits were made:

    i. Aggregates (LANDFIRE). Aggregates are groups of two or more systems mapped together. Because of their focus on vegetation with respect to fire regime, LANDFIRE mapped many wetland systems as aggregates. For example, LANDFIRE mapped an Acadian Salt Marsh and Estuary Systems aggregate, which covered both Acadian Coastal Salt Marsh and Acadian Estuary Marsh systems. Other map producers treated these two systems as distinct map classes.

    ii. System Combinations (TNC). System combinations are essentially the same as aggregates, in that they use a single map class to represent two or more systems that the map producers did not feel they could separate reliably using their mapping methods. However, the system combinations retain the original system names in their legend label, separated by a "/". System combinations were used sparingly in the TNC map, for example, to group blackwater and brownwater floodplain forests.

    iii. Finer-scale Units (LANDFIRE, TNC, SEGAP). The SEGAP, TNC, and LANDFIRE maps all used finer-scale units to represent particular vegetation types where map producers felt that sufficient data were available to parse the system into ecologically meaningful sub-types. The TNC map added systems modifiers to differentiate different wetlands types, moisture gradients, pH, and conifer versus hardwood dominance. SEGAP and LANDFIRE both applied structural modifiers (e.g. herbaceous versus forest) to certain systems, and SEGAP also used modifiers to parse systems based on conifer versus hardwood dominance.

c. Differing treatment of ruderal (semi-natural) versus natural vegetation also causes differences in the map legends. Ruderal vegetation concepts were the least developed of any of the classification concepts at the time these various mapping project began (and although progress has been made, they are still a work-in-progress), so map producers developed their own, less standardized, classification schemes to capture additional detail. The TNC map does not capture ruderal vegetation; rather they treated the vegetation as either "cultural" (urban and agricultural types via the NLCD) or "native." The SEGAP, LANDFIRE, and NatureServe maps all included ruderal vegetation classes, though they did so to varying degrees and without the benefit of standardized map classes. For our map comparisons, we attempted to place similar ruderal vegetation classes used on the different maps into common groupings, but a lack of documentation explaining what each class was intended to represent hindered our ability to truly understand differences in the mapping of ruderal vegetation, and even our broad groupings may be conceptually misaligned.

d. Ecological Systems definitions change over time. NatureServe is actively improving the classification as new data become available which may lead to a change in the system concept or name (e.g. the "Southern Atlantic Coastal Plain Mesic Hardwood Forest" became the "Atlantic Coastal Plain Mesic Hardwood Forest"). One map product used the original name, whereas the other used the updated name. Rarely, in the course of mapping an area, the map producers decided they needed to propose a new system, but that system may not have been available for other map producers to use. The inclusion of a unique identifier (e.g. the code CES203.242 or the ID 723243) in the data would alleviate some of this confusion. This was a relatively small issue in our study, since all four maps largely used the same codes for a given system.
e. Although the NLCD was the primary source for Agricultural types (see Table 2 above), it was treated somewhat differently among maps. The TNC map represents agriculture with a single map class, whereas SEGAP and NatureServe separate row crops from pastureland, and LANDFIRE reports several different agriculture classes, many based on National Agriculture Statistic Services (NASS) classifications.

In order to compare the various maps, it was necessary to reconcile these differences between the map legends. To do so, we created a master map legend (Appendix 1, electronic only) to indicate how each system was mapped by each organization. It includes how aggregates and finer-scale units align with each other among the maps. The master legend also references the unique codes for each map class as used in the source data, thereby facilitating more efficient comparison of the actual data by interested parties. A description of the fields contained in the master legend is provided in Table 3. Users should keep in mind that the geographic scope of the four map products differ; if the master legend indicates that a particular system was not mapped by a specific entity, that can either be an indication of a difference in targets between map products, or due to the fact that the particular system does not occur within the extent of that particular map.

Because the maps cover different areas, the master legend alone was insufficient to discern real differences in mapping targets among map products. To remedy this, we performed a more thorough comparison of map targets for just the area where all four maps overlap in Virginia and West Virginia (Figure 2). This comparison can be found in the section **Ecoregion-based Comparisons in the Region of Overlap of All Maps** and provides a more concrete illustration of differences in the legends between maps.

Table 3. Master map legend fields and guide to formatting.

Field Name	Description & Use
Sort Order	A numeric value used to sort data in the correct order with regard to data groupings.
Unique Code	Typically the ESLF code for standard systems and aggregates. Finer-scale units are rolled up to the systems level for this field. Non-standard systems are assigned a code from the source data.
CES Code	Standard CES code to reference the Ecological Systems Classification
Primary Class	"X" in this field indicates that the listed entity is a "primary class" for the map comparisons; i.e. a map class at the systems level. Blanks indicate aggregates and finer-scale units.
Aggregate Unit	Name of the aggregate, or system combination, if applicable.
System	Standard System Name
Finer Scale Unit	Name of the finer scale unit, if applicable. Because TNC finer-scale units can be due to differing values in any of a number of attribute fields, finer scale units for the TNC map are assigned numerical identifiers (e.g. North Atlantic Coastal Plain Pitch Pine Lowland 1-4). A second tab in the digital version of the Master Legend (the "TNC multiples" tab) indicates the nature of the difference between types.
Lookup Codes	For any system included in the map, these columns report the unique reference code in the source data. Blanks indicate that a system was not included in that map within the NECSC region. An "X" indicates that the system was mapped, but using finer-scale units, the codes for which are provided separately in the rows underneath.
Hierarchy	Additional information on how each mapped vegetation class fits into the NVC Hierarchy.
Comment	Used to provide additional information on any vegetation classes that did not fit neatly into the table (particularly ruderal types).
Guide to table formatting: *Thick lines surround all systems and finer-scale units falling within a given aggregate; the aggregate is given in the first row of the grouping in* ***bold*** *text.* *Thin lines surround finer-scale units falling within a system.*	

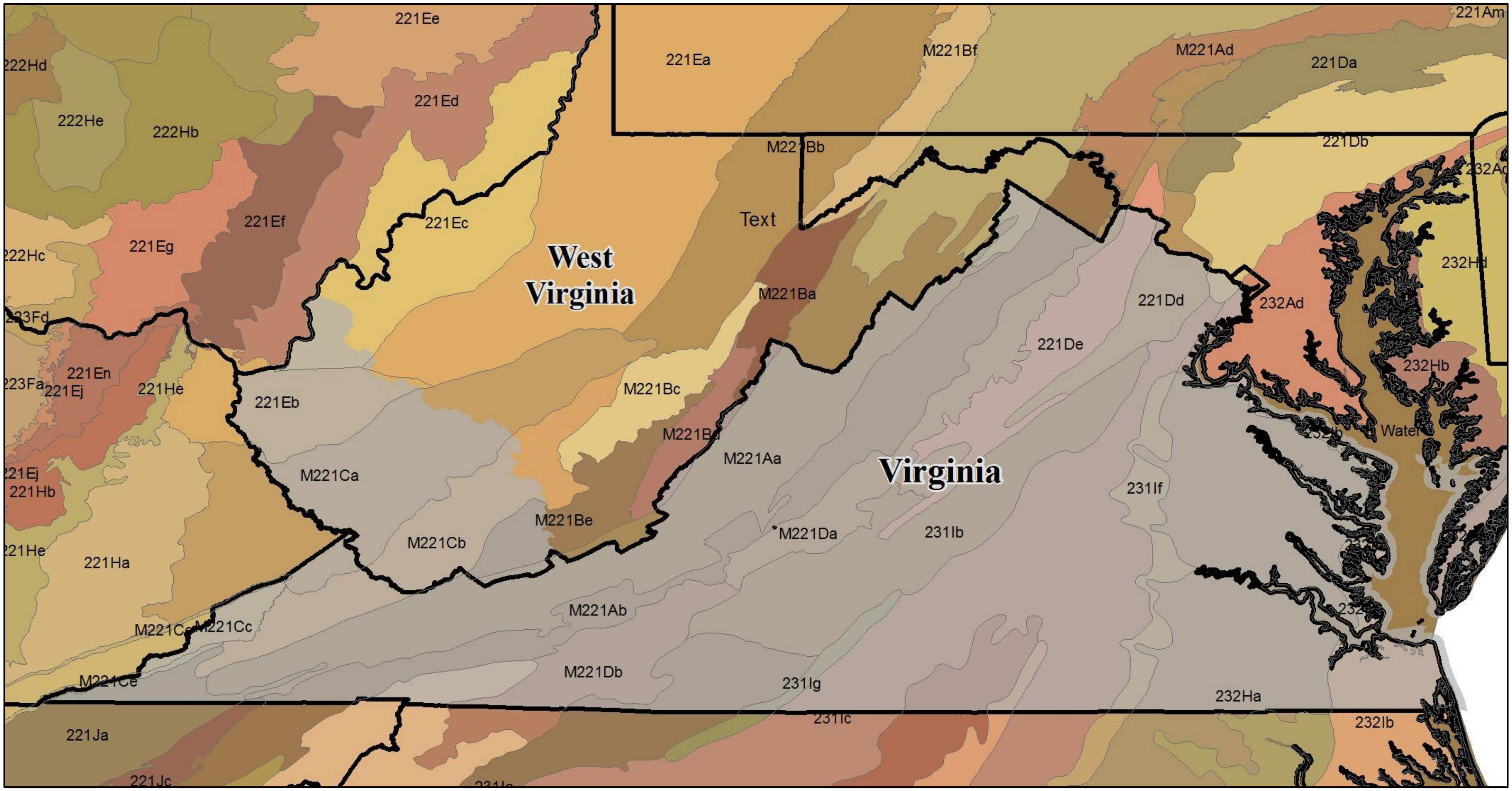

Figure 2. Map of the area of overlap of all four map products shaded in gray. Dark black lines represent state boundaries. Areas shaded in multicolor and labeled with alphanumeric codes are USFS Subsections.

Input Data and Mapping Methods

LANDFIRE, SEGAP, and TNC all used 30-m resolution Satellite Imagery and digital elevations models (DEMs) in some fashion as basic input data to create maps. Other ancillary data, including surface geology, soils, and distance to wetlands or streams, were used by SEGAP and TNC. NatureServe provided modifications to either the LANDFIRE map or the SEGAP map, mainly by adding floodplain and riparian details to LANDFIRE, using additional state Natural Heritage Program data (e.g. for tallgrass prairie), using soil layers, and by re-assigning types where they were mapped out of range.

Two primary methods were used to generate maps: (1) classification of units (pixels or polygons) using training data generated from plots that had been assigned to types, and (2) classification of types based on ancillary data via map overlays using data such as surface geology, soils, landform types, floodplain data layers, etc. (Figure 3). These methods were mixed by both TNC and SEGAP, whereas LANDFIRE used only the first. TNC and NatureServe performed no analysis of raw satellite imagery, whereas SEGAP and LANDFIRE began with satellite imagery.

TNC did not map disturbance (ruderal) types, apart from incorporating anthropogenic types (urban and agriculture) from the NLCD. LANDFIRE used both NLCD results for some cultural types (e.g. agriculture) and direct classification of pixels assigned to ruderal/successional types. SEGAP used interpretations of land cover by site type (e.g. evergreen forest on a deciduous forest site type was a pine plantation) as well as NLCD results. Thus, TNC mapped fewer disturbance types than LANDFIRE and SEGAP, but not a great deal less area in most ecoregions. For example, for the area of overlap between LANDFIRE and TNC, LANDFIRE mapped 34.7% non-natural types (including ruderal), whereas TNC mapped 28.5% non-natural types, a 17% difference.

General Methods Used to Generate Maps

- Classification of units based on explanatory data
  - classified sample plot + units (pixels or polygons) + explanatory data = mapped type
- Map overlays using ancillary data (surface geology, soils, landforms, floodplain data layers, etc.)
  - original type assignment + ancillary data = new type

Figure 3. General methods used by LANDFIRE, TNC, NatureServe, and SEGAP to generate maps.

LANDFIRE

LANDFIRE generated a different map for each map zone (MZ) within the footprint of the NECSC independently (see http://www.LANDFIRE.gov/dp_quality_assessment.php) using broadly similar methods (Figure 4). About 27 map zones overlap the NECSC study area. Seven different combinations of authors, involving six different individuals, are listed as compilers of fourteen map zone summary reports that were available for review for this report. Mapping was based on assignment of plots to lifeform (e.g. deciduous forest, evergreen and mixed forest, shrubland, etc.) and to ecological system type using an automated key, which was in turn derived from “sequence tables” based on vegetation composition. Each plot was assigned to an ecological system or other map legend target element thought to occur within the MZ based on the species composition of the plot. Mapping groups were then formed by segmenting (creating spatial subdivisions of) each MZ, usually using (1) supervised image classification using plot data to define major lifeforms, and (2) geophysical setting masks; most often, a valley bottom zone mask that was developed by LANDFIRE. Number of mapping groups (segments) ranged from 2 to 9 with a mean of 7 across the fourteen MZs reviewed. Target ecological systems were mapped within each mapping group via supervised classification based on plot data where each plot was assigned to a target ecological system type. Number of mapped types ranged from 9 to 41 across map zones reviewed, with a mean of 22. The NLCD was used to define agricultural and urban types, as well as water.

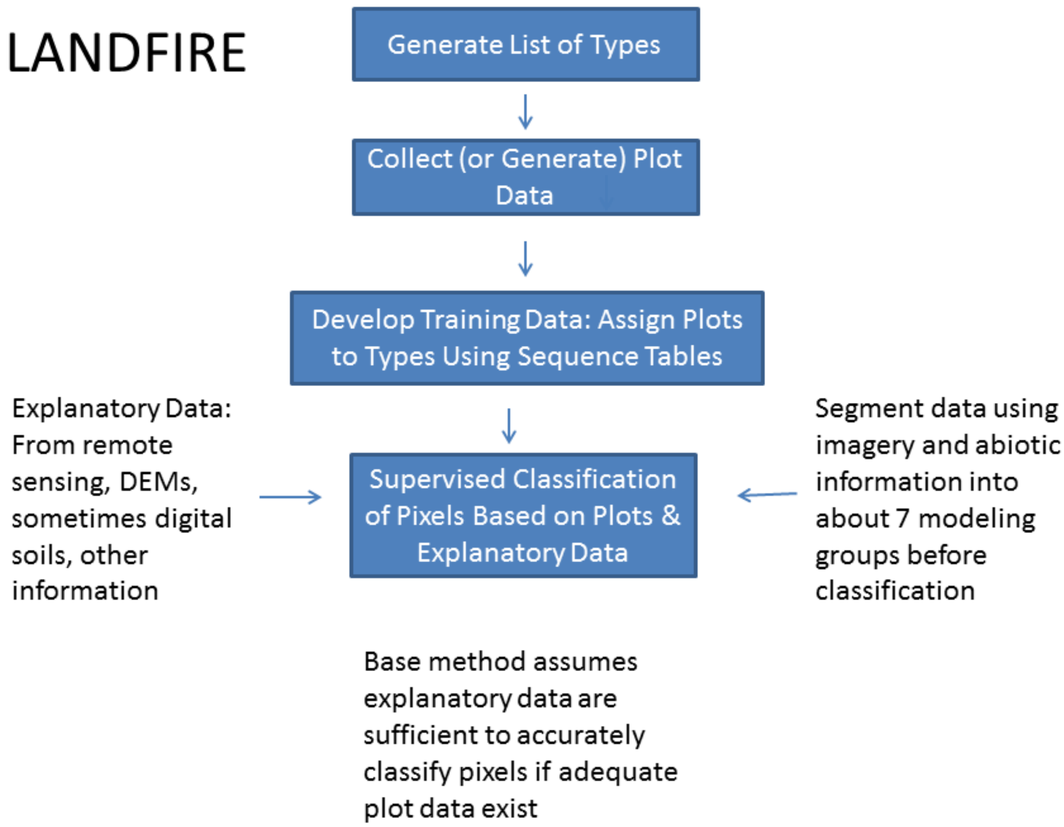

Figure 4. General methods used by LANDFIRE. Each Map Zone (about 27 form some portion of the footprint of our study area) was mapped independently using related but not identical methods, with at least six different workers involved.

Southeast GAP

The SEGAP product was developed by different workers using variable methods (see Kleiner 2007). Workers performed some supervised (with training data from plots classified to system) and some unsupervised (without training data) pixel classifications of satellite data. Ancillary data were also used to map types via map overlays (e.g. land cover + ancillary data layer = mapped type). Ancillary data included range enforcements, usually using ecoregion lines, as well as spatial queries (map overlays) using a variety of other data layers (e.g. soils, surface geology). Kleiner (2007), mapped 50 types: seven directly as NLCD types from unsupervised classification, 10 from NLCD types via range enforcement (e.g. evergreen forest in different ecoregions may have been assigned different ecological system types), 22 via spatial query (e.g. map overlays), six using manual image interpretation, and 5 via ‘individual systems mapping’ that involved a variety of techniques (Figure 5).

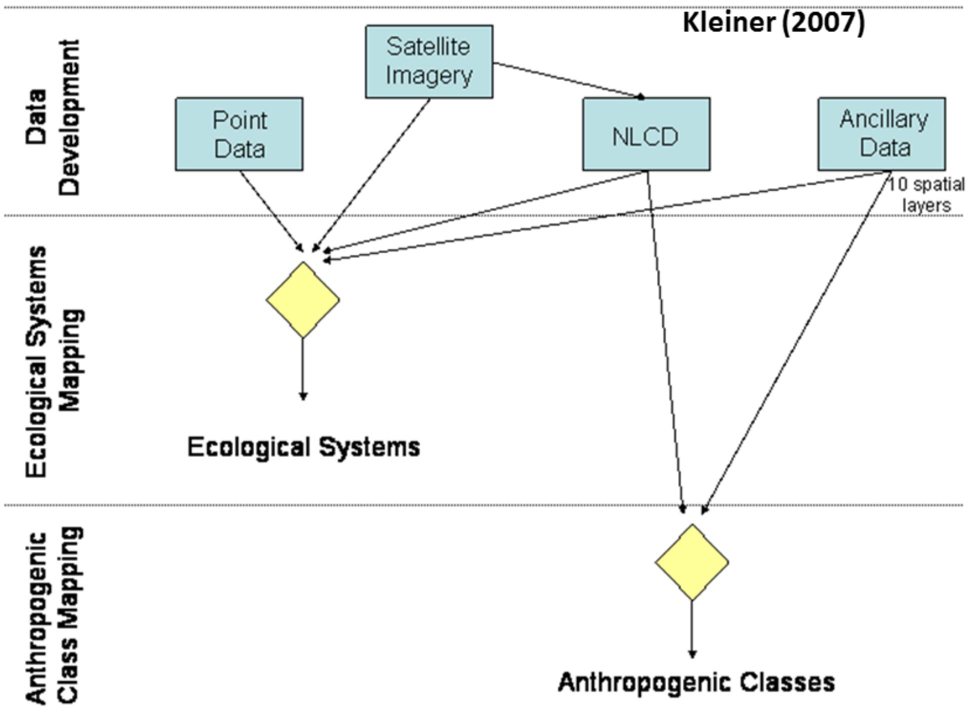

Figure 5. General methods used by Kleiner (2007) for the southwestern portion of the SEGAP analysis area. Most types were mapped either from NLCD types via range restrictions, or via spatial queries using ancillary data (e.g. map overlays).

The Nature Conservancy

The Nature Conservancy (TNC) map producers first had NatureServe staff and other experts lead an effort to review, and revise, the ecological systems classification for the mapping area (Gawler 2008). System range distributions were also reviewed. TNC then used two different methods to map current distributions of ecological systems, one in rugged landscapes and one in flatter landscapes (Ferree and Anderson 2013). Ultimately, both approaches relied heavily on (1) assigning landform patches to matrix ecological system types, and (2) use of ancillary data to model non-matrix system types (e.g. map overlays). First, in rugged landscapes that comprised the bulk of the area mapped, they performed supervised classification (using RandomForest software) of 100 acre hexagons using explanatory data assigned to hexagons and classified plots as training data. Hence, each 100 acre hexagon was assigned a prevailing matrix system. This is similar in concept to classifying pixels, but the spatial units (100 acres [40 ha] versus 30 square meters) are different, and the explanatory data did not include satellite remote sensing data. Next, landform patches derived from a 7-class landform model were assigned to an ecological system type within each hexagon. Most often, each patch (e.g. summit/ridgetop, low hill/valley) was assigned the matrix type for the hexagon that circumscribed the patch. Thus, classification results were transferred from 100 acre hexagons to smaller landform patches based on results from the RandomForest classification. In some cases, landform patches were assigned to a different type than the classification indicated for the hexagon in which they occurred. For example, a mesic landform patch (e.g. cove) within a given hexagon may have been assigned a more mesic type than what was assigned to the hexagon from classification results. In this way, the characteristics of landform patches (e.g. dry, typic, mesic) were reflected in the classification results. Second, in flatter landscapes (the Coastal Plain and Northern Lake Plain ecoregions), system types were assigned by expert judgment directly to landforms based on mapped known occurrences of system types, the NLCD and NWI and other more local land cover information, and site relationships gleaned from system maps in immediately adjacent ecoregions. Once matrix types were assigned (15), non-matrix types (85) were mapped mainly using ancillary data via map overlays (Figure 6). Hence, 85% of all mapped types were generated via map overlays.

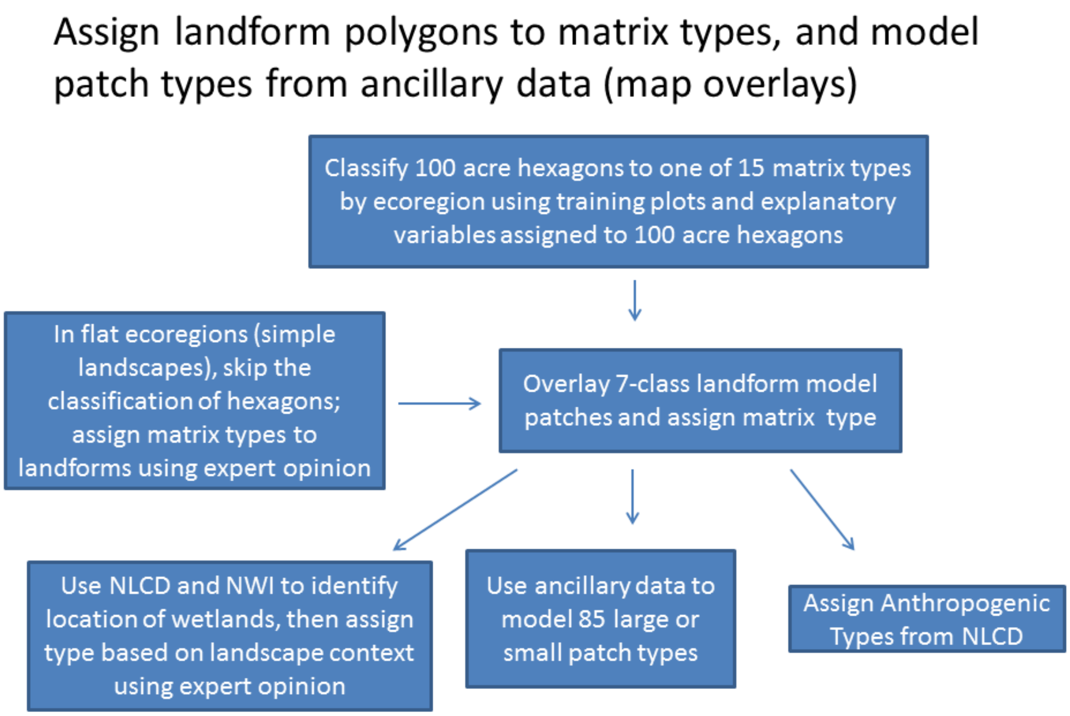

Figure 6. General methods used by TNC. Matrix types (15) were assigned to landform patches generated from digital elevation models, and non-matrix types (85) were modeled using ancillary data.

NatureServe

NatureServe's existing national aggregate map of ecological systems and land cover in this region was generated from the original LANDFIRE and SEGAP maps (NatureServe 2009, Smyth et al 2013). NatureServe ecologists earlier provided consultation and tools for labeling sample plots to both SEGAP and LANDFIRE efforts. In order to facilitate the review of the original maps, we calculated the total area mapped for each type by USFS ecoregion. NatureServe's regional ecologists used that information to flag ecological systems that appeared, based on expert judgment, to be over-represented or under-represented in each given ecoregion, systems that were mapped outside their expected range, and systems that were not mapped at all in ecoregions where they are known to occur.

In order to evaluate existing maps and create deductive models, it is necessary to first have georeferenced records of known occurrences of particular vegetation types. To this end, we created a geodatabase of sample data compiled from multiple sources, including state Heritage Program community element occurrences, classified wetland monitoring plots in Michigan and Ohio (Faber-Langendoen et al. 2011), and detailed vegetation maps from National Park Service Units including Apostle Islands National Lakeshore (NL), Effigy Mounds National Monument (NM), Grand Portage NM, Indiana Dunes NL, Isle Royale National Park (NP), Ozarks National Scenic Riverway (NSR), Pictured Rocks NL, Saint Croix NSR, Sleeping Bear Dunes NL, and Voyageurs NP. NatureServe has established the relationship of all of the mapping units in these vegetation maps to the ecological systems classification.

In order to assess the accuracy of the base map, and target systems for revisions, we undertook both a quantitative map validation using data in the observation geodatabase and a systematic type-by-type visual review of the distribution of all mapped types. Systems that were flagged earlier as having distributions that were over or under-represented in the region as a whole, or within certain ecoregions, received additional scrutiny.

In March, 2012, NatureServe ecologists held a two-day workshop to complete a type-by-type review of systems, in which the results of the quantitative accuracy assessment were considered in conjunction with a visual examination of the extent of each mapped type. The goals of this review were to (1) identify and document misrepresentations in the source data, and (2) develop strategies for addressing and rectifying those problems. This included identifying and removing map classes that should not have been included in the original map. The workshop was followed by additional internal map review of systems not adequately covered during the workshop.

In several cases, the strategies identified for improving errors in the source data required the development of biophysical data sets. Spatial data on soils, hydrology, and canopy cover were used to improve the mapped distribution of several mapped types.

Using NatureServe's aggregate map of ecological systems as a starting point, we completed map revisions. For example, in the Midwest, the revisions affected seventy map classes and approximately twenty percent of the total mapped area (Smyth et al 2013).

Comparison of Mapping Methods

Identification of overall pros and cons of each map is difficult, because 'universal/categorical' truths are generally not in evidence due to variation among and within maps (Table 4, Table 5). TNC mapped the fewest ruderal types, but not much less disturbance area. Their map was based on landform patches, and therefore is less 'pixelated' and more aesthetically pleasing than other maps. Whether this also reflects a more accurate map is not clear. Because types are mapped systematically along environmental gradients, results are ecologically logical, with more mesic types mapped on more mesic landforms and drier types mapped on drier landforms. Land cover, however, was not accounted for at a fine resolution, so evergreen versus deciduous trees were not separated as different sub-types within a given ecological system, as they were by SEGAP. Both TNC and SEGAP mapped a limited geographic region. LANDFIRE relied on supervised classification which is driven by plots, and this process introduces issues when samples of target types are insufficient, or are lacking entirely. Each of the 27 map zones overlapping the footprint of our study region was mapped independently, often by different workers, and results were merged to product a final map. This process resulted in difficult to track variation related to differences in methods and outcomes among map zone products. They also separated map producers from ecologists in a compartmentalized map production process, so on-the-fly adjustments to mapping targets resulting from give and take between ecologists and technical map producers was apparently not possible. The NatureServe map is a combination of the LANDFIRE and SEGAP maps, with modifications designed to improve the product added. Issues with spatial rectification are sometimes apparent in this map, but are not uniform across the extent of the study area. Some areas are as much as 90 m out of alignment with other georectified data layers. This issue limits the utility of the map for some purposes, for example, analyses that rely on alignment with our data layers like streams, roads, or boundaries of management units. Caution is needed only when comparing the NatureServe map with the other maps within a spatially-specific context, and not when analyzing summary data across larger areas.

Table 4. Summary of products reviewed and methods used by different map producers for the footprint of the NECSC.

Mapping Effort	Date	Mapping Targets (Natural Types)	Treatment of Disturbance Types	General Methods	Comments
LANDFIRE - Existing Vegetation Type (EVT); USFS; see Rollins et al. 2006, Rollins 2009	1999-2001 satellite data initially; areas that changed were re-mapped for the 2008 refresh; areas that changed were re-mapped for the 2010 update	Ecological Systems, Aggregates of wetland and sparsely vegetated systems, and selected Alliances	>50 non-system targets, including NASS identified agricultural types, numerous developed types, ruderal types, plantations (along with recently logged modifier), introduced vegetation, and others	Plot samples were assigned to target types to generate training data for mapping within each map zone. Workers used three dates of satellite imagery plus environmental variables to classify pixels. In most Map Zones, workers stratified the data for each map zone based on lifeform and abiotic masks and then classified each strata separately (e.g. deciduous forest was stratified, and then plots within this strata were used to classify the deciduous forest targets).	Methods varied by map zone. NatureServe and cooperators generated sequence tables to assign plots to target types (based on floristics, mainly) for mapping. New efforts are underway to provide a refresh, and this will include new sequence tables assigning plots to both Ecological Systems and, in some regions, Groups in the National Vegetation Classification (NVC).
The Nature Conservancy (TNC); see Ferree and Anderson, 2013	NLCD 2001 & 2006 (Piedmont & Mid-Atlantic); results largely from geophysical variables (geology, elevation, topography, solar inputs), not remote sensing	Ecological Systems modified in some cases based on abiotic site type (e.g. mesic or dry versions of a given ecological system on differing sites)	Urban and Agriculture types were burned in directly from the NLCD; non-system shrublands/grasslands and pine plantations were also included for some regions	Workers assigned 100 acre hexagons to matrix forest types by ecoregion using Random Forest classification models generated from plot samples. Explanatory variables assigned to the hexagons were largely abiotic, plus NLCD major cover type summaries. A 7-class landform model was then overlain on hexagons and patches of landform units were assigned to matrix ecological system. These assignments were modified based on expert judgment (e.g. mesic landforms were assigned a more mesic forest type than the matrix type for the hexagon). Smaller patch ecological system types were modeled by expert judgment (e.g. assigning types to abiotic sites where possible). Some types were burned in from known, mapped locations.	In the North Atlantic Coastal Plain and Great Lakes ecoregion, mapping was done by combinations of land cover, landform (land position, rugosity), and region using expert judgment. Wetlands were mapped using NWI, NLCD, and expert judgment. All actions taken to produce the map are documented and illustrated. Up-dating the current results using NLCD, LANDFIRE disturbance types, and additional modifications seems very doable with moderate effort, and results will be easy to interpret.
Southeast GAP (SEGAP); see Kleiner 2007	1999-2001 original satellite imagery	Ecological Systems modified by land cover (e.g. a pine and an oak type in pine-oak systems)	Several types from NLCD (Developed and Agricultural types), successional shrub/grass, and plantations	Partners split the study region by map zone. Mapping targets were classified directly by supervised classification of samples, were modeled based on inclusion/exclusion masks, and were mapped from expert decision rules applied using abiotic variables (e.g. a deciduous forest in a given region over a given soil type might be modeled as some specific type).	Some modifications of this data layer have been made over the years, and the current version is still listed as provisional. This layer will be refreshed as part of the GAP mosaic refresh based on the 2011 NLCD and LANDFIRE new disturbance layers. Workers will be part of the new LANDFIRE data production effort by 2015 and beyond.

Table 4. Summary of products reviewed and methods used by different map producers for the northeastern USA (continued).

Mapping Effort	Date	Mapping Targets (Natural Types)	Treatment of Disturbance Types	General Methods	Comments
NatureServe (National Map); see Smyth, Drake and Menard 2013	1999-2001 mainly; modified EVT and SEGAP	Ecological Systems and disturbance types as mapped by source classifications	Reliant on the source classifications: LANDFIRE EVT and SEGAP	Workers merged the SEGAP map, where available, with the EVT elsewhere and performed additional modifications. Modifications include reclassification of types mapped outside of their known range, adjustment of types that were apparently grossly over- or under-mapped within their range, improvement of EVT aggregates for wetlands, and addition of some rare types. Regional ecologists were consulted to review the distribution of all mapped systems in the Midwest and select systems elsewhere and recommend best approaches for improving the map.	Additional individual changes have been made for some types and have been tracked. The results of this effort are directly connected with the original source classifications. Range changes will be Incorporated into the new LANDFIRE refresh effort. Going forward, NS is focused on working with LANDFIRE to ensure the production of a high quality product.

Table 5. Major positive and negative map outcomes related directly to methods.

Mapping Effort	Positive and Negative Outcomes Related to Methods
LANDFIRE - Existing Vegetation Type (EVT); USFS; see Rollins et al. 2006, Rollins 2009	increased number of ruderal types mapped; variation specific to map zones occur since each map zone was done independently; variation in methods from zone to zone, and compartmentalizing of tasks (ecologists largely separated from remote sensing & GIS staff at the time of map production), make interpretations of questionable outcomes difficult; not many wetland types mapped; up-dating seems certain in the near future
The Nature Conservancy (TNC); see Ferree and Anderson, 2013	ecologically logical and cartographically elegant maps; use of patches eliminates 'salt and pepper' look of pixel-based outcomes; good documentation results in easy to interpret maps; apparent tight links with local ecologists resulted in some needed up-dates; limited number of disturbance types mapped; assumes landforms as modeled influence vegetation in a predictable way; polygon-based outcome makes changes easier; limited geographic scope and uncertain up-dating
Southeast GAP (SEGAP); see Kleiner 2007	limited accessible documentation reduces the ability to interpret of outcomes; land cover-based modifiers of mapped types add information; not likely to be re-done; limited geographic scope
NatureServe (National Map); see Smyth, Drake and Menard 2013	begins with LANDFIRE or SEGAP so carriers the issues inherent in both but incorporates targeted improvements to address short-comings in the source data; each modification gets farther from the source data and these modifications are done in several different ways; may or may not be re-done, but edits have been provided to LANDFIRE 2015 efforts; in addition to seams in original maps, seams are added where SEGAP and LANDFIRE products meet; georeferencing issues may cause problems when map is used within a spatially specific context at fine resolution

Quantitative Map Product Comparisons

Several steps were required in order to accomplish a quantitative evaluation of the map products. We first acquired the data from each of the four efforts. Several of the efforts are updated on a regular or irregular basis, so we chose a set of versions and focused our analysis on those versions. The versions were identified as:

1) The Nature Conservancy (TNC): 2012 (syst_ne120607)
2) LANDFIRE EVT: 2008 (v1.1)
3) NatureServe: 2013 (v2.9)
4) Southeast GAP: 2008

NECSC Footprint Map Comparisons

We defined the extent of the evaluation relative to the footprint of the existing data and area of interest for the NECSC. The resulting extent is provided in Figure 1 (see above), and includes the full extent of TNC's map. We included areas south to incorporate the entirety of the Appalachian Landscape Conservation Cooperative, and west to include areas recently updated by NatureServe in the eastern portion of the Midwest. Each of the products was clipped to the extent of the analysis, except TNC's product which was included in its entirety.

Two separate analyses were undertaken to elucidate the differences among the products. The first was a pixel-to-pixel comparison where we evaluated the mapped type that one producer attributed to a pixel, compared to the mapped type the other three producers attributed to the pixel. The advantages of this analysis are that it allows extent-wide comparison, and it allows identification of types with which a mapped type is confused among products. It is, however, sensitive to minor spatial discrepancies. The second analysis focused on the area of overlap among all four products in Virginia and part of West Virginia. The area of each mapped type was calculated within each subsection where data was available. This method was robust against minor spatial discrepancies, but is limited in scope to the overlap zone and does not provide direct information regarding specific mapped types among which confusion has occurred.

In order to accomplish a pixel-to-pixel comparison we registered each of the products to LANDFIRE EVT (existing vegetation type) by modifying the headers of the working copies of the raster products such that pixels were aligned. To accomplish this we examined common land covers (each effort used the NLCD product to a greater or lesser extent and we were able to look at pixels for those land covers) across the range of each of the products. This process allowed us to align the TNC, LANDFIRE, and Southeast GAP products. The NatureServe product showed inconsistencies across the extent, with some areas showing alignment, while a shift of up to 90 m could be observed in different parts of the extent. This lack of alignment made pixel-to-pixel comparisons for the NatureServe product somewhat suspect, though the error was more exaggerated for mapped types that were highly pixelated or linear, and for areas further away from the area where alignment was close (the southeastern portion of the extent). Also required for the comparison was a standardization of the legends for each of the products, and re-classing each of the products to the common legend (as documented above). Once the products were spatially and thematically registered, comparisons became feasible.

The actual comparison was accomplished using the crosstab function within the RASTER module of the statistical package R. This allowed extent wide comparisons, because comparisons only produced values where the extent of a pairwise comparison was identical. For instance, any comparison that included TNC's results only considered the overlap area between TNC's product and the product of the producer to which TNC was being compared. The analysis provided six confusion matrices showing counts of pixels mapped by one producer as a mapped type versus another producer. These pairwise comparisons were symmetric, large, unwieldy, and sparse. They were symmetric in that they provided one table that showed the relationship between two products; one could view how producer A mapped a type versus how producer B mapped a type, and vice versa. They were sparse in that many cells of the matrix were 0, where no pixels were mapped for many mapped type comparisons. These matrices took the form of typical accuracy assessment tables, but accuracy was not implied.

To make the comparison process more interpretable, we condensed the large tables into easier to understand condensed tables (Appendix II). The condensed tables provide the number of pixels mapped as a type for product A and then provided a percentage of those pixels that were mapped as the same type or other types for product B. These tables were asymmetric, requiring 12 tables to evaluate each pairwise comparison between products. The legends were not identical, with some producers mapping finer scale types than others and some producers mapping types that did not have clear one-to-one congruence between the legends. This made comparisons difficult, but overall congruence among the products is summarized for this analysis as:

NatureServe vs. Southeast GAP:	90.8%
LANDFIRE EVT vs. TNC:	50.2%
TNC vs. NatureServe:	43.7%
LANDFIRE EVT vs. NatureServe:	43.3%
Southeast GAP vs. TNC:	42.3%
LANDFIRE EVT vs. Southeast GAP:	32.3%

While these percentages may seem low (except for NatureServe vs. Southeast GAP which is a result of NatureServe primarily using the Southeast GAP product where it was available), they are surprisingly high, given the extent of the efforts, the differences in methodology, and the large number of possible types among which the producers could have chosen to attribute to a particular pixel. Additionally, this comparison allowed little flexibility relative to spatial or thematic differences. That is, if producer B did not map the exact same mapped type at the exact pixel as producer A, it was considered a "mismatch." In particular, some of the concepts for the mapped types are quite similar and this comparison failed to give any credit for "near misses."

As an example, Table 6 shows the relationship among 6 mapped types which appear to show consistent confusion among the types. The analysis suggests that differences among the products may result from, a) confusion among the concepts of what the type represents, b) differences among the products relative to how types were mapped along a moisture or substrate gradient, or c) differences in how geographic distribution of the type was used.

For instance, LANDFIRE EVT primarily mapped Southern Ridge and Valley / Cumberland Dry Calcareous Forest from central Tennessee southward, while Southeast GAP mapped the type up to southern Ohio and through western Virginia. LANDFIRE EVT mapped fairly large amounts of Allegheny-Cumberland Dry Oak Forest and Woodland in southern Tennessee and southward, while Southeast GAP gave it a more northerly distribution with concentrations in West Virginia and Kentucky. The two products may have also used different information regarding substrate, thus resulting in differing distributions relative to this important differentiator between the two types. For Southern Appalachian Oak Forest, Southeast GAP constrained the distribution to the Blue Ridge and mapped it through Virginia in this ecoregion, while LANDFIRE EVT allowed it in other ecoregions but only mapped it from southern West Virginia southward. Classification comments suggest that the Allegheny-Cumberland Dry Oak Forest may be thought of as a subtype of the Southern Appalachian Oak Forest, indicating that mapping confusion between these two types may result from concept confusion between them.

For major types covering large areas and showing discrepancy among the products, we produced maps showing the extent of the types for each of the products as in Figure 7. The four-panel images were examined but suggested a large array of differences with multiple and interacting reasons for the differences. It was hoped that this evaluation would shed light on some basic corrections that could be readily applied for some set of maps, but the extent of the differences and the complexity of the reasons precluded our ability to provide a detailed solution (but see below, where a general recommended solution is provided).

To a limited degree, we examined whether concurrence among the products was improved if macrogroups from the USNVC were used instead of systems. Macrogroups are coarser, thematically, and it may be that aggregating the systems into these coarser units may reduce the influence of variations in abiotic or geographic effects on the products. It may also buffer the influence of concept fuzziness, allowing similar types (that may be difficult to map differentially) to be combined. For instance, The Appalachian & Northeastern Oak - Hardwood & Pine Forest Macrogroup (M502) includes 14 systems: Allegheny-Cumberland Dry Oak Forest and Woodland, Appalachian Shale Barrens, Central and Southern Appalachian Montane Oak Forest, Central Appalachian Pine-Oak Rocky Woodland, Northeastern Coastal and Interior Pine-Oak Forest, Northeastern Interior Dry-Mesic Oak Forest, Northeastern Interior Pine Barrens, Northern Atlantic Coastal Plain Hardwood Forest, Northern Atlantic Coastal Plain Maritime Forest, Northern Atlantic Coastal Plain Pitch Pine Barrens, Southern Appalachian Montane Pine Forest and Woodland, Southern Appalachian Oak Forest, and Southern Ridge and Valley / Cumberland Dry Calcareous Forest, and Northern Atlantic Coastal Plain Calcareous Ravine. Mapping these systems together as a macrogroup provides the result as shown in Figure 8. Looking at only this macrogroup among the four products suggested a higher degree of concurrence at the Macrogroup scale of resolution. For this macrogroup and averaging among the 12 comparisons, there is a 65.2% concurrence. For all the systems in the macrogroup among the 4 products, there is a 31.8% concurrence. Such a comparison fails to control for the relative importance of each of the types within the macrogroup and across the mapped landscape, but does suggest a convergence of the products at that resolution. So, there is an increased concurrence among the products at the expense of decreased thematic resolution of the products.

Table 6. Six mapped type showing consistent confusion among one another. Data is derived from comparisons between LANDFIRE EVT and SEGAP products and between EVT and TNC products. EVT column indicates the mapped type with which other products are compared. SEGAP and TNC columns indicate mapped types attributed to the pixels mapped by EVT as the type in the EVT column, with the percentage of those pixels that were mapped as types listed in the SEGAP and TNC columns. Bold font indicates a “match.” Only types representing greater than 10% of the pixels are listed unless a sub-type of the EVT mapped type is included (bold, but no percentage).

EVT	SEGAP	TNC
Allegheny-Cumberland Dry Oak Forest and Woodland	**Allegheny-Cumberland Dry Oak Forest & Woodland:Hardwood (42%)** Southern Ridge & Valley Dry Calcareous Forest:Hardwood (25%) South-Central Interior Mesophytic Forest (10%) **Allegheny-Cumberland Dry Oak Forest & Woodland-Pine**	**Allegheny-Cumberland Dry Oak Forest & Woodland (27%)** Northeastern Interior Dry-Mesic Oak Forest:typic (23) Southern Appalachian Oak Forest:typic (22%) South-Central Interior Mesophytic Forest (13%)
Appalachian (Hemlock)-Northern Hardwood Forest	Northeastern Interior Dry-Mesic Oak Forest:Hardwood (42%) Southern & Central Appalachian Cove Forest (12%) **Appalachian (Hemlock)-Northern Hardwood Forest**	**Appalachian (Hemlock)-Northern Hardwood Forest:typic (39%)** Northeastern Interior Dry-Mesic Oak Forest:typic (22%) **Appalachian (Hemlock)-Northern Hardwood Forest:drier** **Appalachian (Hemlock)-Northern Hardwood Forest:moist-cool**
Northeastern Interior Dry-Mesic Oak Forest	**Northeastern Interior Dry Oak Forest-Hardwood (45%)** Southern Ridge & Valley Dry Calcareous Forest:Hardwood (14%) Southern & Central Appalachian Cove Forest (11%) **Northeastern Interior Dry Oak Forest:Mixed** **Northeastern Interior Dry Oak Forest:Virginia/Pitch Pine**	**Northeastern Interior Dry-Mesic Oak Forest:typic (45%)** Appalachian (Hemlock)-Northern Hardwood Forest:typic (16.89%) Central Appalachian Dry Oak-Pine Forest (12%) **Northeastern Interior Dry-Mesic Oak Forest:moist-cool**
South-Central Interior Mesophytic Forest	Allegheny-Cumberland Dry Oak Forest & Woodland:Hardwood (32%) **South-Central Interior Mesophytic Forest (28%)** Southern Interior Low Plateau Dry-Mesic Oak Forest (19%)	**South-Central Interior Mesophytic Forest (32%);** Northeastern Interior Dry-Mesic Oak Forest:typic (23%) Allegheny-Cumberland Dry Oak Forest & Woodland (17%) Southern Appalachian Oak Forest:typic (17%)
Southern and Central Appalachian Cove Forest	Southern Appalachian Oak Forest (29%) Southern & Central Appalachian Oak Forest:Xeric (16%); **Southern & Central Appalachian Cove Forest (14%);** Northeastern Interior Dry Oak Forest:Hardwood (10%)	Northeastern Interior Dry-Mesic Oak Forest:typic (22%) Southern Appalachian Oak Forest:typic (19%) South-Central Interior Mesophytic Forest (12%) **Southern and Central Appalachian Cove Forest:acidic** **Southern and Central Appalachian Cove Forest:calcareous** **Southern and Central Appalachian Cove Forest: circumneutral**
Southern Appalachian Oak Forest	**Southern Appalachian Oak Forest (27%)** **Southern & Central Appalachian Oak Forest:Xeric (24%)** Allegheny-Cumberland Dry Oak Forest & Woodland:Hardwood (15%) Southern & Central Appalachian Cove Forest (11%)	**Southern Appalachian Oak Forest:typic (45%)** Allegheny-Cumberland Dry Oak Forest & Woodland (26%) **Southern Appalachian Oak Forest:moist-cool**

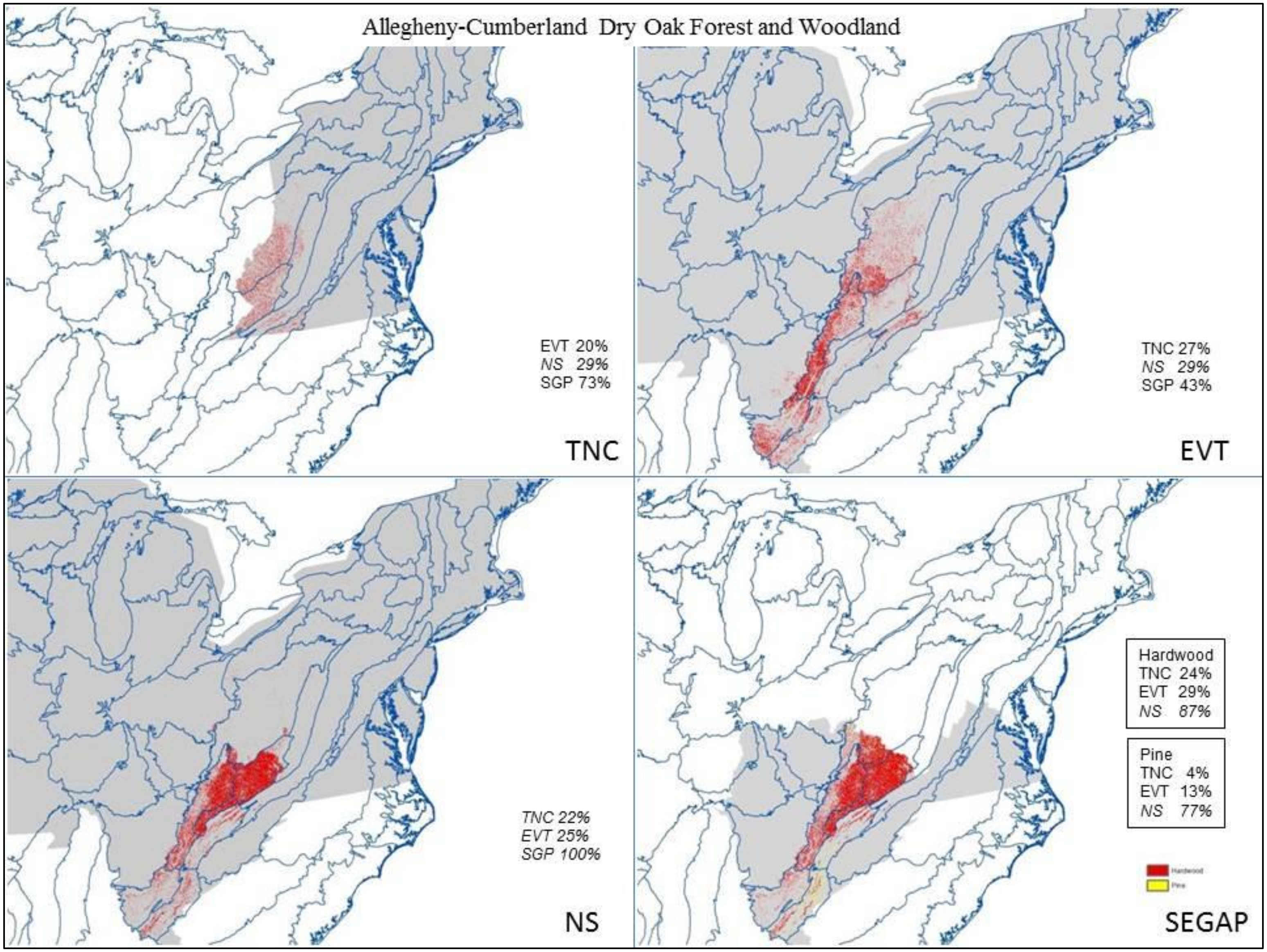

Figure 7. Depiction of the extent of Allegheny-Cumberland Dry Oak Forest and Woodland as mapped in each of the four products (TNC upper left, LANDFIRE EVT upper right, NatureServe lower left, Southeast GAP lower left). Blue lines represent USFS Section boundaries, gray shading represents the extent of the product, and red or yellow represents the extent of the mapped type. Percentages indicate the percent of the mapped pixels from a product that were mapped as the same type in the three other products. For example, 20% of the pixels mapped in the TNC product were also mapped as the type in the LANDFIRE EVT product. Southeast GAP mapped two sub-types within the mapped type.

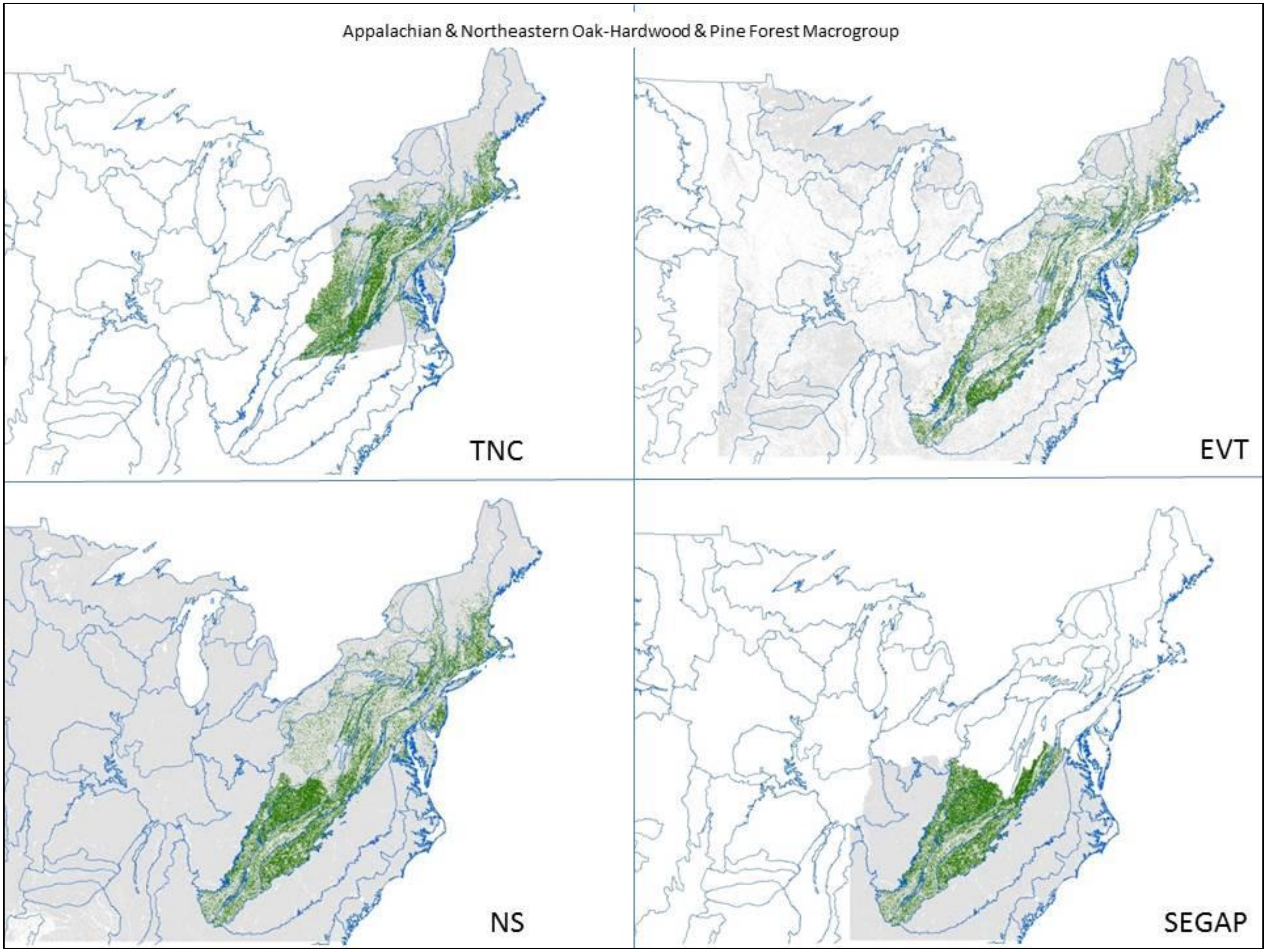

Figure 8. Illustration of the Appalachian & Northeastern Oak – Hardwood & Pine Forest Macrogroup as mapped in the four products. Blue lines represent USFS Sections and dark green represents the distribution of the macrogroup.

Ecoregion-based Comparisons in the Region of Overlap of All Maps

The second type of analysis was limited to the area in Virginia and part of West Virginia where all four products overlapped (see Figure 2, above). This analysis involved summarizing the area of each mapped type for each USFS Subsection (ECOMAP 2007). The analysis generalized any minor spatial discrepancies among the datasets, and allowed us to evaluate the maximum difference in area for each mapped type in each subsection among products. It also gave us a measure of the geographic distribution of differences among the products for each mapped type. For instance, for each mapped type, we counted the number of subsections where the type made up more than 10% of the area of the subsection mapped and where the type differed by greater than 10% among the products (Table 7).

Using this approach, we determined that map products for Northeastern Interior Dry-Mesic Oak Forest differed in 12 subsections, indicating a fairly geographically widespread difference among products. Similarly, the Southern Piedmont Dry Oak – (Pine) Forest differed in 7 subsections, and the overall difference in area mapped among products was comparable to the Northeast Interior Dry-Mesic Oak Forest (largest difference for the former is 7,709 sq. km. and for the latter is 8,128 sq. km.). Many of the same mapped types that were highlighted as showing marked confusion among the products at the scale of the NECSC footprint were also identified using this ecoregion-based analysis.

Within the area of overlap, a total of 85 systems were mapped by at least one of the map producers, with only 25 of those systems, <30%, mapped by all producers. An additional 30 systems known to occur in the area were not mapped by any of the producers. Differences in what was mapped could be traced to several causes:

(1) The mapping of systems outside their expected range. The mapping methods used by all producers necessitated decisions about the geographic extent of system distributions. Often, map zones or ecoregional lines were used to constrain a given system to particular areas (LANDFIRE, SEGAP, NatureServe), or mapping rules dictated the most likely matrix system in a particular geography (TNC). Fourteen of the 85 systems mapped were not expected to occur within the geography being compared based on the conceptual classification information (i.e. state and ecoregional tabular attributions) alone. This highlights the fact that map products, based on methodology and plot assignment, did not concur with the distributions of the target types as understood by a separate (or overlapping) set of ecologists attributing systems to ecoregions and/or states. The vast majority of those, however, occur in proximity to the region and in some cases, the classification information itself is somewhat unclear as to the precise extent of the system. Consequently, different map producers made different decisions about where to draw ecoregional breaks, resulting in the observed differences. For example, the TNC map extends several systems into Virginia whose classification concepts are limited to more northern geographies; given that the TNC map has a focus on Northeastern vegetation, this is not altogether surprising.

(2) Different approaches to smaller patch types. Because both the focus of the mapping efforts and the methods employed differed among map producers, the degree to which small patch types were mapped also varied. TNC targeted several wetland, barrens, and cliff types that other producers did not attempt to capture, while SEGAP/NatureServe mapped an additional bog and fen type and an additional cliff type not mapped by others, as well as several wetlands types that LANDFIRE and TNC had only captured as aggregates or as combined system classes. LANDFIRE, in comparison, targeted few map classes not captured by others.

(3) An additional 30 systems known to occur in the area were not mapped by anyone, further highlighting the discrepancy between ecologists' understanding of the distribution of target types and the distribution of those types as depicted by the products. These include (1) several small patch systems that are difficult to accurately map including seeps, glades, cliffs, and ponds; (2) linear types including river-courses, ravines, beaches and bluffs, and (3) wetland and aquatic types including seagrass and aquatic beds, tidal marshes, peatlands, and lakeshores.

(4) Differences in thematic resolution. As mentioned previously, the four map producers utilized aggregates and finer-scale units to varying degrees to capture vegetation concepts. This both complicates our direct comparison of mapping targets, and also has implications for users interested in particular map units. For example, both within the zone of overlap and elsewhere, LANDFIRE aggregates many wetland systems together while TNC breaks those same systems into finer-scale map classes based on wetland characteristics.

(5) Different spatial resolutions: raw 30m data vs. smoothed 30 m data vs. whatever TNC did. These are important mapping methods to mention in this context.

Table 7. A listing of mapped types making up greater than 10% of any subsection and differing in amount mapped by greater than 10% among products in the area where the four products overlapped. The count of the number of subsections where difference is greater than 10%, sq. km. of the type mapped overall in the overlap zone, largest difference in sq. km. among the products, and the rank of the difference from 1 (largest difference) to 10 (10th largest difference). Yellow cells indicate smallest area mapped, orange cells represent largest area, and blue cells highlight the top ten types with largest differences.

		sq. km					
Mapped Type	**Count of Subsections Differing by >10%**	**EVT**	**NS**	**SEGAP**	**TNC**	**Largest Difference**	**Difference Rank**
Allegheny-Cumberland Dry Oak Forest and Woodland	13	4,312	11,551	14,675	4,599	10,363	1
Northeastern Interior Dry-Mesic Oak Forest	12	5,087	9,102	12,796	11,200	7,709	5
Southern Appalachian Oak Forest	12	3,591	2,644	4,121	10,329	7,685	6
South-Central Interior Mesophytic Forest	9	9,636	2,546	989	4,455	8,647	2
Southern Piedmont Mesic Forest	9	5,710	1,845	1,263	9,849	4,447	10
Appalachian (Hemlock)-Northern Hardwood Forest	8	3,453	5,330	691	565	4,765	9
Central Appalachian Dry Oak-Pine Forest	8	3,265	4,183	1,018	4,309	3,291	
Southern and Central Appalachian Cove Forest	8	5,743	3,446	3,890	2,213	3,530	
Southern Piedmont Dry Oak-(Pine) Forest	7	7,905	14,553	15,400	7,272	8,128	3
Managed Forest	5	9,135	9,034	9,351	4,559	4,792	8
Ruderal Forest	5	7,837				7,837	4
Southern Ridge and Valley / Cumberland Dry Calcareous Forest	5	150	2,171	4,216	3,622	4,066	
Successional Grassland & Shrubland	3	1,038	3,767	4,138	4,140	3,102	
Agriculture	2	28,000	23,183	23,226	23,914	4,817	7
Herbaceous Wetland	2	989	5			989	
Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	2	451	2,760	2,760		2,760	
Atlantic Coastal Plain Nonriverine Swamp and Hardwood Forest	1			418	762	762	
Northern Atlantic Coastal Plain Hardwood Forest	1	856			2,594	2,594	
Southern Appalachian Northern Hardwood Forest	1	1,229	21	37	52	1,208	
Atlantic Coastal Plain Mesic Hardwood Forest	1	3,961	2,814	2,813	4,522	1,709	

Case Study: Prince William Sound Forest Park

To better understand differences among maps, we performed a detailed comparison of mapped vegetation on the ground at a single location (Figure 9). We used Prince William Forest Park, in northern Virginia, as our case study. We chose this location because it is within the area of overlap for all four maps, a detailed National Park Service vegetation map has been completed for the area, and the Park is located in a transition area between several ecoregions, illustrating the challenges of ecosystem mapping in transition zones.

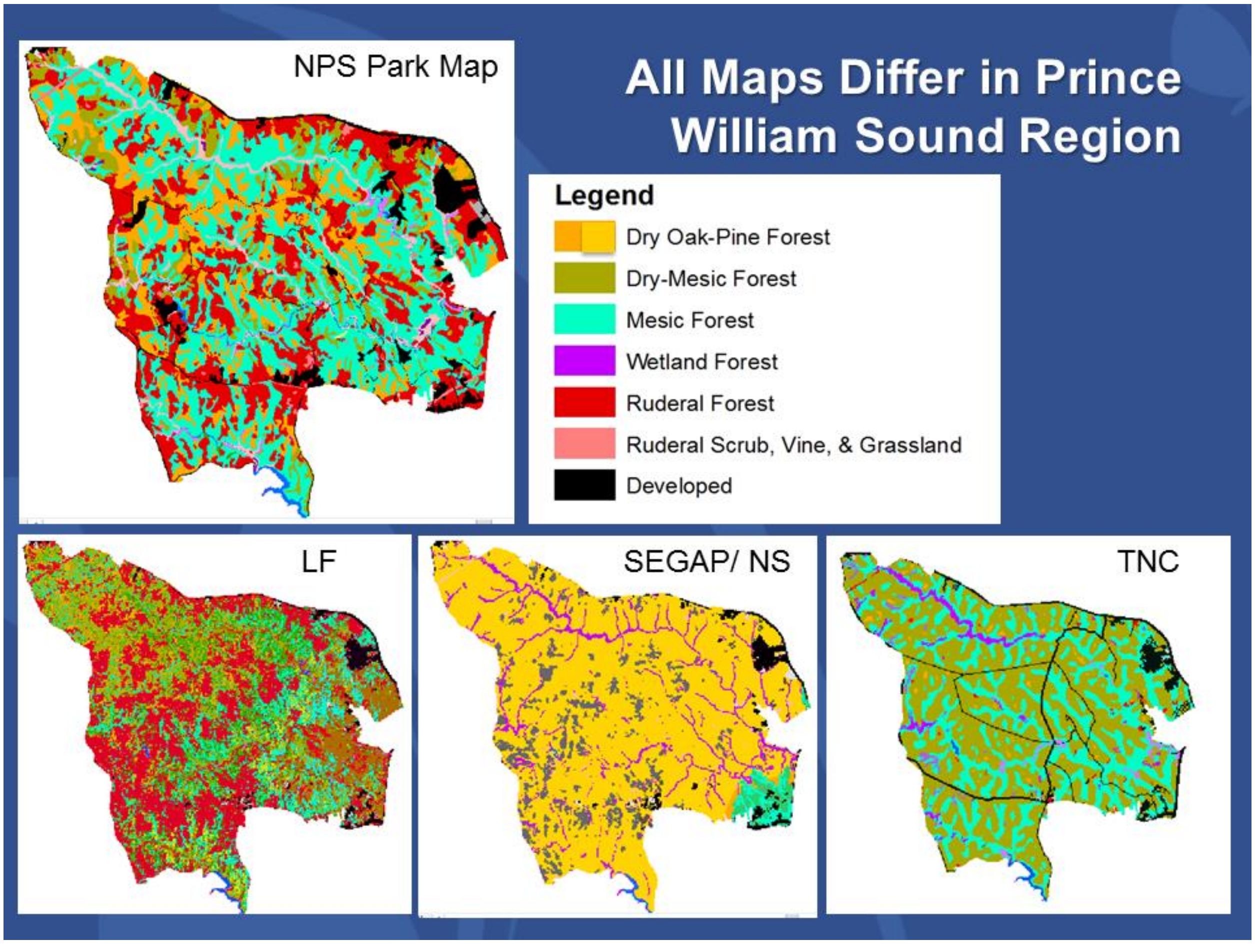

Figure 9. Prince William Sound Forest Park was selected as a case study to compare all four maps evaluated. The legend was generalized to reflect the basic ecological patterns. NPS = National Park Service, LF = LANDFIRE, SEGAP = Southeast GAP, NS = NatureServe, TNC = The Nature Conservancy. The NPS map was based on aerial photo interpretation. The other 3 types of maps are based on remote sensing imagery.

In order to assess differences among maps in this area, we visually examined the maps themselves, compared the total area mapped for each system in each map, and used NPS plot data to perform a "pseudo accuracy assessment" of each map. Because the NatureServe and SEGAP maps were essentially identical in this region, we did not assess them separately.

Observed differences closely tracked the differences uncovered in our larger analysis. Specifically, maps differed due to (1) actual differences in mapping targets, (2) conceptual differences in what targets were understood to represent, (3) differences in the use of range restrictions, (4) differences in the treatment of cultural and ruderal types, and (5) differences in the mapping methods, including varied reliance on geophysical setting for map overlays in generating results.

Our initial map comparison revealed map products that at first glance appeared to differ greatly. Not only did the "look" of the map vary among products (with the TNC map largely reflecting landform gradients and the LANDFIRE map showing much greater pixilation), but the actual mapping targets varied greatly both among the systems maps and compared with the finer resolution NPS map. On closer inspection however, those differences could largely be explained by different interpretations by map producers about the extent of related systems within an ecoregional transition zone and along a moisture gradient.

Prince William Forest Park is located near the boundary between Piedmont and Atlantic Coastal Plain ecoregions, in an area where vegetation transitions from more southerly-associated systems to more northerly ones. For example, while NPS documented a large quantity of South Atlantic Coastal Plain Mesic Hardwood Forest within the Park, TNC instead mapped Southern Piedmont Mesic Forest and LANDFIRE mapped both the Atlantic Coastal Plain mesic type and Appalachian (Hemlock)-Northern Hardwood Forest, a mesic forest type more often found to the north. While we might consider the map "wrong" for these systems, the reality is that it is difficult to distinguish between some of these systems within transition zones even when on the ground. The classification comments for the South Atlantic Coastal Plain Mesic Hardwood forest report:

> *"Differences from mesic forests of the Piedmont are sometimes fairly subtle, and species that differentiate them in one part of the range many not work in other parts. In particular, some species that are excluded from the Coastal Plain farther south are common components farther north. In MD and DC, this system can extend into the Piedmont, straddling the fall zone where the Coastal Plain and Piedmont meet."*

In addition to ecoregional gradients, forests in this area transition from wet to dry. The majority of the park area, as documented by NPS, fell into one of three systems along this gradient: Southern Atlantic Coastal Plain Mesic Hardwood Forest, Northeastern Interior Dry-Mesic Oak Forest, and Central Appalachian Dry Oak-Pine Forest. The TNC, LANDFIRE, and SEGAP/NatureServe maps varied in the degree to which they adequately captured this gradient, with TNC and LANDFIRE (to a somewhat lesser extent) mapping larger quantities of dry-mesic forest and SEGAP/NatureServe mapping larger quantities of dry forest. Again, discerning differences between systems along these subtle gradients can be difficult to do even on the ground.

Finally, TNC did not attempt to map ruderal types (which were most often disturbed or restored mesic and dry-mesic forests), but in this particular landscape, those types occupied a moderately substantial part of the park. For that reason, the TNC map differs rather strongly from the other maps. SEGAP does map the ruderal types, but did not pick them out in this particular landscape.

It is difficult to identify a "best map" even when looking closely at one particular area. The TNC map provides users with a map that makes 'ecological sense' along moisture and topographic gradients; but in this case, it did not identify the dry end of the gradient. The LANDFIRE map best attempts to capture both the moisture gradient and the disturbance types in the park.

As none of the maps are intended for use at the fine-scale resolution undertaken in this example, care should be taken to not over-interpret the results for any map. Given our observations however, it is clear that maps that originally appeared to be in overwhelming disagreement were revealed to actually reflect similar vegetation patterns, albeit with some differences in the labeling of map classes at the systems level. It is likely that much of the dissimilarity between maps observed at regional scales also reflects these patterns.

Map Comparison Summary

Several reasons for differences among the products came to light as a result of these analyses. The mapped types (legend entities) differed among products, both actually and conceptually. The actual differences in types used among the products were apparent when developing the common legend. This was particularly true relative to cultural (non-natural) and ruderal (semi-natural) types where a standard nomenclature was lacking. This was less of an issue for native or natural types, though different products mapped types at different thematic scales. For instance, LANDFIRE EVT used system aggregates for some bottomland and riparian types, whereas other products mapped the systems themselves. LANDFIRE EVT and NatureServe products generally used the system as the finest scale natural type, whereas SEGAP used landcover modifiers and TNC used abiotic characteristics to map at finer thematic resolution. Conceptual differences of the types among the products results from the fact that producers may have interpreted the concepts of systems somewhat differently and therefore used different rules to accomplish their mapping. The concepts for the types are often not strictly bound by vegetation composition, abiotic characteristics, or geographic boundaries and are therefore open to interpretation. The producers differed in their reliance on geophysical setting and remote sensing data for mapping systems, and they had different sets of plots and used different methods to attribute the plots to a particular system to use as training data in supervised classifications. Range restrictions of the types were used differently among the producers, and data relating to the ranges of the types were inconsistent among the map producers. Map producers differed in the amount of map overlays used in mapping, especially with respect to small scale system occurrences. Input data also differed among the products, and methods generally differed substantially among the products (see Input Data and Mapping Methods section).

Phase III and IV: Developing Recommendations for an Improved Regional Map

We present Phase III and IV first, as they follow most directly from Phase I. Phase II is presented after this section.

Regional Meeting

We facilitated a meeting of key partners, including the producers of all maps reviewed and some map users, in order to help develop recommendations for an improved map. Appendix III provides a detailed summary of the meeting. All PowerPoint presentations given are available for viewing of download at: http://northatlanticlcc.org/projects/land-cover-reconciliation/meeting-folder. These presentations represent the best overall summary of the content of the meeting. A key outcome of this effort was simply getting all map producers together to explain methods and discuss issues. Among map producers, LANDFIRE, now in collaboration with national GAP, is the only one that plans a comprehensive revision. This effort will focus on national needs of the LANDFIRE/GAP programs for production of a nationally-consistent product, and cannot address many more regional and local needs. SEGAP will not produce a new regional product, but will continue to modify their existing results to a limited extent. NatureServe continues to support national mapping efforts and relies on modification of maps as they are produced. TNC had produced a map over a limited extent, and can only provide additional coverage if funded locally or regionally. The extent to which these map producers can cooperate to provide a single map product remains uncertain. Continued funding and production of a limited number of regional, state, and local maps across the country to meet specific needs seems certain.

Developing an Improved Map

Issues in Developing an Improved Map

The fairly wide differences among maps we observed may derive from (1) trying to map at a scale of mapping resolution that is too fine for reasonable accuracy given the time, funding, and methods used, (2) compounding of apparent mismatches among maps when reasonably accurate maps are overlain (e.g. two maps that are 70% accurate, when overlain, may show vast differences), or (3) compounding of mismatches when related but not identical types are mapped in the same area. Issues (1) and (3) both relate to the nature of vegetation itself in that a rainbow of variation occurs between and among described modal types. To address the first issue, current maps can be collapsed into fewer types at the macrogroup level (see Figure 8 and associated discussion, above). The NLCD map provides a second solution, if only the most basic categories are needed, and it is straight-forward, understandable, and likely to be repeated over time. Products from the NLCD such as percent impervious cover, percent forest cover, and change may be useful independent of the NLCD land cover map. The map products presented here are focused on getting better ecological maps completed, and simply mapping fewer types is not a comfortable solution for all users.

Map users within the footprint of the NECSC have a variety of needs that may be served best by a variety of different mapping products. Thus, a ‘better map’ may mean different things to different users. A comprehensive analysis of user needs was not within the scope of this study. Nonetheless, a uniform map at the finest practical spatial and thematic resolution would be useful to most users. Unfortunately, in our judgment, there is no reason to believe that any of the maps we reviewed is inherently more accurate than the other maps overall. No independent data exist to make that evaluation. Such a data set would have to be collected in a reasonably randomized way, and would have to be stratified by mapped type for each map (e.g. samples designed to fall within mapped types, after mapping). These types of data sets are unlikely to be collected in the near future. Expert review and identification of issues has resulted in some recent map improvements, especially in the NatureServe and TNC maps, and these types of efforts will likely prove fruitful in the future.

Users interested in particular vegetation types might consult the master legend (Appendix 1) to see how that type was treated by each map, and thus which maps are of greatest interest given their needs. Only the NatureServe and LANDFIRE maps cover the entire NECSC footprint, and hence these are the best maps for users who need summary information across the entire area. The NatureServe map is in general an improved map versus LANDFIRE and SEGAP, and is hence the best whole-region solution available. That said, the TNC map appears to be the strongest product in Northeastern states insofar as it is ecologically logical and outcomes are easy to track back to methods, though as with other maps, its accuracy has not been well tested. It does not however capture ruderal vegetation in much detail. Hence, incorporation of information from LANDFIRE into the TNC map might improve results in terms of relating to vegetation condition and provide a more useful product within the footprint of the TNC map. Either extending methods used by TNC to a larger area, or incorporation of TNC results into the NatureServe map, might provide a useful improvement.

Proposal for a better map in the NECSC Footprint

Because of large and inconsistent differences among maps reviewed, and the time it took to sort through comparisons, we were unable to provide a better map product directly. Our work did help to enhance version 3.0 of NatureServe's National Map. And currently that map is probably best map for users who want a comprehensive map for the NECSC footprint, which includes the Northeast and Midwest regions. Still, more could be done. A relatively short-term option for producing a higher-quality regionally consistent map would be to merge the TNC map into the NatureServe National Map. This would capitalize on the strength of the TNC map in the Northeast and capture the review and improvements to the LANDFIRE and SEGAP products NatureServe has already undertaken in the Midwest and Southeast, thus providing the best available map given existing products. Doing so would entail the following tasks:

- Replacing the LANDFIRE data in the Northeast with the TNC map, relying on the master legend (Appendix 1) developed for this project to ensure consistent classification across map products

- Expert review of the map comparison tables (also from this project) for the zone of SEGAP/LANDFIRE/TNC overlap to make determinations about how to constrain/reclassify systems where the maps come together in a manner that best reflects real ecoregional constraints and minimizes edge-mapping issues.

- Burning LANDFIRE data on ruderal types into the final product to ensure consistent representation of ruderal types across regions. At this stage, we could also consider assessing (1) whether data from SEGAP with modifiers should be re-coded in the national map to better reflect the ruderal nature of those vegetation classes, and (2) whether other data products (e.g. representations of land use change from NLCD) could be used to update the map as a whole.

- For all systems whose distributions were reviewed and revised as a component of the IUCN systems Red-Listing work (see http://www.iucnredlistofecosystems.org/about-us/ongoing-initiatives/alaska-patagonia/), make determinations about whether and how to integrate those changes into the areas covered by the TNC map (those revisions are already incorporated into v3.0 of the National Map elsewhere). For systems not already reviewed as either a component of the Midwest Map Review or IUCN projects, review the distribution in the merged map product and make adjustments as necessary to maximize map accuracy.

- Develop more complete documentation on the National Map methodology, including information on source data, changes made, and observations on map class accuracy (See “Improving the Map Legend” section below). This information, as well as the data itself, would be designed to facilitate display and use of the map at the different thematic scales of interest to users (e.g. Macrogroups) while also pointing users to finer-scale units available by directly using the source data.

The resulting map would represent a merging and modification of three efforts, and thus would incorporate map seams and variations inherent in each, plus seams and variation resulting from the merging itself. NatureServe used a slightly different spatial rectification from other map producers, with results in a small offset from the other maps in some regions, which would need to be addressed in the merging process. Thus this approach is realistically doable and may result in more uniform and useful results, especially at coarser spatial and thematic resolutions.

Finally, remotely sensed information, independent of classifications, may be useful to help define current condition, and to enhance species modeling in the future. Data generated by LANDFIRE and the NLCD such as canopy height, canopy cover by strata, and impervious cover may be important. This information could be combined and analyzed in concert with variables that relate to geophysical setting, such as geology, soils, landform, slope, exposure, land position, flow accumulation, and others.

Improving the Map Legend

Our review of the four map projects clearly indicates that although they all started from the same classification, ecological systems, their methodology and their ecological expertise led each map producer to produce a different map legend. None of the four maps clearly explain how the map legend relates to the underlying systems classification. Such an explanation would require summarizing the types as mapped, versus using conceptual descriptions of the target types. Because descriptions of ecological systems tend to focus on better quality occurrences of the system, the map legend or map class types of ecological systems are not the same as the ecological systems classification types., This occurs even though the map is attempting to express the spatial (ecological, geographic) pattern of the ecosystem type. Map class description should summarize

- map to classification relations
- mapping process, and
- ecological content of the map class

MAP LEGEND TEMPLATE (DRAFT)

NAME

A. Map Class Name:

B. Relation of map class to ecological system type(s)

- E.g. a) aggregate, b) directly equivalent, c) complex, d) new system.
- Reason for relationship.
- Classification type name reference.

MODELING PROCESS

C. General citation for mapping methods.

D. Mapping approach (including post processing)
E. Model parameters (number of plots, ancillary data, etc).
F. Validation and AA.

MAP CLASS DESCRIPTION

H. Map class ecological description(?) (geography, acres, ecology).

Figure 10. Example of a map legend template. Developing a map legend template allows the users to understand how a set of classification types was used to guide the map legend, while recognizing that classification type cannot always be mapped directly.

An example of a map legend template is provided in Figure 10. Given that large-area maps need to model the ecosystem types, documentation of the method is essential. Providing a map class description for each type allows users to readily understand how the map was created. Users will often be interested in description and accuracy of individual types, rather than the whole map. Thus we suggest that, as part of an upgraded map for the NECSC, a simple prototype map legend template be created for the map.

Phase II: Extending the Map Legend, Including Climate Change

In the original proposal, we planned to extend the map legend into Canada, and provide an evaluation of climate-sensitive ecoregions with the Appalachian region. Delays and reductions in funding from the original proposal required that we remove this task from the project, as documented via the project interim report.

Map Legend Extension

Map legends were compared and, to the extent possible, reconciled (Appendix 1). Map producers extended the map legends beyond available ecological systems in a variety of ways, including:

- Adding land cover modifiers to ecological systems (e.g. evergreen and deciduous forest land cover for a give ecological system type). This was done mainly by SEGAP. For example, hardwood cover in uplands within the Longleaf Pine range is an indicator that this evergreen system has been converted to either a mixed coastal plain oak – hardwood system or, if longleaf pine was cleared and plowed and then farming ceased, the site could succeed to a ruderal hardwood type.

- Adding moisture regime modifiers based on landform models to ecological systems (e.g. mesic or xeric phases of a given ecological system). This was done by TNC.

- Adding disturbance types. This was done in a variety of ways, mainly by LANDFIRE and SEGAP. As discussed earlier, new additions to the NVC, or development of more standardized taxonomy for disturbance types outside the NVC, may help standardize disturbance types in the future..

Map producers mainly did not modify types based on forest canopy closure or height. These variables are newly available from the NLCD and LANDFIRE, and may prove useful to characterize current conditions in future maps. As currently available (e.g. polygon format), the TNC map would be easiest to modify by adding land cover modifiers or disturbance types from other efforts.

Ecosystem Vulnerability to Climate Change

The Northeast Climate Science Center provides information to land managers to aid in their anticipation and monitoring of, and adaptation to, climate change. Support of the production of an integrated and coherent map of ecological systems across the region served by the Northeast CSC is a necessary first step towards meeting this goal; equally important is the need to understand the vulnerability of these systems to climate change.

Although conducting *de novo* climate change vulnerability assessments was ultimately beyond the scope of this project, we did compile a list of 34 existing ecosystem vulnerability assessments from four studies conducted within the NECSC footprint (Appendix IV, digital only). Sources included two studies encompassing the 13 northeastern states (Maine to Virginia, west to New York, Pennsylvania, and West Virginia) (Manomet Center for Conservation Sciences and

National Wildlife Federation 2012a and b – referred to subsequently as "Manomet"); these included ten terrestrial ecosystems (upland and wetland) and one aquatic ecosystem. Another source focused on nine major ecosystems in the Central Appalachian portion of Pennsylvania, West Virginia, and Maryland (Butler et al. *in prep*). Finally, we compiled information for fifteen assessments conducted in North Carolina.

Results of the studies are presented in Appendix IV (electronic only). Ecosystem names used in the assessments, and their corresponding relationship to the Ecological Systems Classification, are illustrated. Manomet and Butler et al. used NatureServe's Ecological Systems Classification, and NCDENR used units defined by the state natural heritage program (Schafale and Weakley 1990).

Vulnerability Assessment Results

The ecosystems deemed to be most vulnerable to climate change shared the following characteristics: a) confined to cool climates, either high elevation or southern range limit (e.g. alpine tundra, spruce-fir, northern hardwood, boreal or montane bog systems); or b) sensitive to hydrologic changes (e.g. stream floodplains).

The ecosystems deemed to be least vulnerable to climate change shared the following characteristics: a) adapted to dry habitats and are characterized by high fire frequency (e.g. pine barren, dry oak-pine systems), or b) systems that range far south and are currently experiencing climate predicted to occur in this region (peat swamps, freshwater marshes).

Other systems fall within a gradient of vulnerability, or have variable responses to predicted climate change due to a number of factors. For example, forests of dry-mesic habitats may support trees that can withstand some degree of climate change, but have herbaceous layers that are sensitive to increased drying.

Although results from each of the studies are largely comparable, there are some important caveats to bear in mind when interpreting the information:

- Ecosystems and their component species vary along climatic gradients, and as a result, may be vulnerable in one part of the range and not vulnerable in others. Therefore, results for wide-ranging systems should be applied only to the general region where the assessment was conducted, and should not be extrapolated to the NECSC footprint as a whole. Both studies conducted by Manomet were assessed in separate climatic zones, and results vary among these zones.
- The use of the term "vulnerable" is applied, or derived, somewhat differently among researchers. For example, Manomet definitions are: Critically Vulnerable = likely to be eliminated; Vulnerable = likely to be relatively unaffected; Less Vulnerable = likely to extend range; Least Vulnerable = likely to greatly extend range. Butler et al. (*in prep*) adopted the definition IPPC (2007) definition of vulnerability, described as the susceptibility of an ecosystem to the adverse effects of climate change. NCDENR reports ecosystem response to climate impacts by likelihood, effect, and magnitude of change.
- Vulnerability to climate change may be assessed strictly, or may also include other existing stressors or factors in the assessment. Manomet studies report both results

separately and in combination; Butler et al. (*in prep*) reports vulnerability as a function of potential impacts and adaptive capacity, independent of cultural values; and NCDENR reports synergistic effects separately.

Lessons Learned

User Needs

- The needs and objectives of the user community will have a great impact on the methodology that should be used in vegetation or ecosystem mapping. It is important to understand, as much as possible, the challenges, opportunities, limitations, and costs of various techniques and data, and how the results will best serve needs.
- Existing maps cannot be retrofitted to meet all user needs. Map producers have a variety of target users and operate under time and budget restrictions. Any given user group may need to fund map producers directly to serve their own needs.

Classification Development

- A standard nomenclature for cultural (non-natural) and ruderal (semi-natural) vegetation and surface disturbance (burned lands, harvested forest, etc.) is needed, as well as descriptions of how these types relate to the natural/native systems/habitats. The USNVC can now be consulted for guidance on some of this nonmenclature.
- Using a multi-tiered spatial and conceptual hierarchy (e.g. formation, macrogroup, system, abiotic or land cover system modifiers, special map units or types where needed) may help both map producers and users develop the finest resolution maps that can be produced given the time and funding available. However, vegetation is continuously changing over time and space, so simply scaling up will not solve all issues: zones where different types overlap, and ambiguous differences between types, will always exist.

Map Legend Description

- Definitions of the proposed mapping units need to be clear at the beginning. A map legend description should be developed including the relationship of mapped types to the ecological systems classification, the geographic range of mapped types, and how different related map units compare to one another in geographic space (a 'mid-Atlantic' and a 'south-Atlantic' Maritime Forest, for example). The methodology by which the map units are developed should also be described (e.g. matrix types through modeling, specialized types through specific rules, and rare types through burning in locations). This information can be described in a map legend template that ties the classification to the map units and methodology.
- If the map is intended to have value in distinguishing different successional phases or vegetation quality variation in the mapped systems/habitats, this should as much as possible be determined ahead of time and these needs accounted for in the methodology.
- Development of descriptive information about the units that were actually mapped, regardless of the initial set of targets to which the mapping effort was directed, would be helpful. This may include vegetation descriptions of the actual mapped types from samples, abiotic parameters associated with the mapped types, and peculiarities in the

methodology relative to specific mapped types where the methodology strayed from the standard used throughout the remainder of the effort.

Mapping Methodology

- Additional plot data and standardized methods for assigning plots to legend entities would contribute to better products. These plots can take the form of full floristic plot data or simpler observations, as long as sufficient data is provided to characterize the plot relative to the legend elements. Each of the producers used plot data to drive significant portions of the efforts. Some mapped types are under-sampled or lack plots altogether. Mapping types that lack adequate ground data constitutes a recurring and significant issue, and results in more problems when methods rely almost entirely on plot data, rather than incorporating map overlays for mapping. In addition to plots being used for inductive modeling, deductive modeling, and validation, these plots can be used to characterize the mapped types and clarify the relationship of the mapped types to the conceptual descriptions of the legend elements.
- Ancillary data (soils, geology, hydrology, elevation) often relate to slowly changing enduring features (EFs) of the landscape. The development and use of a standard set of EFs as an aid to mapping and modeling would be desirable. Abiotic drivers of vegetation vary by region, and different EFs might be more or less important in different ecoregions. Thus, the form of EF data may not be a single, universally-applied polygon-based result, but rather a standardized set of EFs and suggested standard ways to depict an array of individual abiotic variables.
- Use of EF data layers to model selected ecological systems was a common mapping method employed by all map producers to a greater or lesser extent. Enduring features can be accurately mapped in a repeatable way, but this is not to say that the way in which EFs help define the distribution of ecological system types is perfectly understood. Furthermore, the relationship of EFs to vegetation types will not remain constant over time.
- Results for most users will be enhanced when map producer teams include both remote sensing interpreters and ecologists, who stay in communication throughout the project. This will enhance the team’s ability to recognize problems and modify methods or mapping targets during the mapping process, which will improve practical results.

Climate Change

- Climate change will impact each individual species in unique ways across multiple environmental gradients. For this reason, along with unknown impacts from invasive species, pests, and interactions among species, currently recognized ecological systems may be significantly altered, or may be replaced by new types, in the future.
- Even with a highly accurate map of ecological systems/habitats today, predictions related to impacts of climate change on these types in the future will be problematic. It is not certain that a given ecological system in a mountainous region will simply move upslope or to more mesic site types in response to increasing temperatures. A given type as it exists currently may morph into a new type due to different responses of a wide variety of species. Hence, the future suite of ecological systems will certainly not match currently defined types in a seamless, 1:1 way. The distribution of

types as related to abiotic variables (e.g. break points among types along abiotic gradients) will likely change over time as well.

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List of Appendices Available in Digital Form Only

Appendix I. Master map legend for the footprint of the NECSC. Relationships among mapping targets used by LANDFIRE, TNC, SEGAP, and NatureServe and summarized.

Appendix II. Condensed map comparison confusion matrix summarizing major differences among LANDFIRE, TNC, SEGAP, and NatureServe results.

Appendix IV. Results of habitat vulnerability assessments compiled from recent studies (see Manomet (2012a, 2012b) and Butler et al. (*in prep*).

Appendix III – National Meeting Summary

Comparing Existing Ecological Systems Maps for the Eastern USA
Compiled Meeting Notes
June 13, 2014
David Diamond

Following are meeting notes organized around the meeting agenda. PowerPoint presentations given at the meeting can be found at:

http://northatlanticlcc.org/projects/land-cover-reconciliation/meeting-folder

The PowerPoints represent the best summary of this meeting. Notes below focus on capturing discussion items that came in the afternoon, and largely do not repeat what can be gleaned from the PowerPoints. The summary is based on a compilation of original notes from Lee Elliott of MoRAP, Don Faber-Langendoen of NatureServe, and Renee Vieira of the NALCC. I have placed editorial comments within the notes.

9:00 Opening Remarks & Introductions (Scott Schwenk and Michelle Staudinger)

Brief summary of the importance of this project to the NECSC and associated LCCs. Results of this meeting and the summary report may help define a way forward.

9:15 Opening Set-up (David Diamond)

- Workshop Outline – background first with time for discussion, followed by presentations by map producers, and a long discussion section at the end
- Differences in Perspectives & Issues in Common
- Common Input Information for Map Production
- Methods Used

Discussion during and after this presentation included comments on the ability to define mapped types. Nobody has actually set out to sample vegetation within mapped type boundaries to define the composition and variation of mapped types, nor has anyone summarized existing samples by mapped type. This could be done (e.g. by summarizing the tree composition of all FIA plots assigned to a map unit). Human disturbance has altered the landscape in some regions such that vegetation on the ground does not conform to descriptions of types that appear in the literature or as summarized in the ecological systems description. Sometimes on-the-ground variation is substantially at odds with descriptions in the literature. Thus, a name assigned to a mapped type may not accurately describe the composition and variation within that type on the ground.

One participant noted that we might be trying to map too many types, and that accuracy could be improved if we map fewer types. Definition of mapping targets is the first step. Adding a macrogroup level above systems may also provide a way to roll up current map units to a more accurate level.

10:00 Creating a Common Legend of Mapped Types (Don Faber-Langendoen and Regan Smyth)

- Process for Creating a Common Legend
- Who Mapped What: Aggregates, Fine-scale Units, & Ruderal Vegetation
- Virginia/West Virginia Case Study
- Map Legend Description

One participant again stated that mapped types may not need to be so fine-resolution for bird modeling.

There was discussion of ruderal types and the fact that TNC used ruderal types from NLCD only. It was noted that possibly LANDFIRE ruderal types could be used to improve the TNC map by 'burning them in.' There was confusion in that some thought TNC did not map ruderal types; they did map ruderal types, just not as many in terms of number of different types – but similar in area. Currently, it was noted that LANDFIRE seems to have mapped too many similar/overlapping/confusing ruderal types.

A marsh type mapped too far south by TNC was mapped that way because of the lack of a defined southern type - this was a known issue to be dealt with, and relates to the overall need to better define mapping targets and tighten up type concepts.

The concept of using <u>map classes</u> different from concepts within the NVC or ecological systems was introduced and discussed. Map classes have the potential of helping to solve the problem that may arise when no existing type from the literature fits the vegetation that is actually on the ground. This topic is also related to the need to characterize legend elements as they are mapped.

10:45 Break

11:00 Comparison of the Maps (Lee Elliott and Regan Smyth)

- General reasons for differences
- Pixel by pixel evaluation
- Ecoregion by ecoregion evaluation
- Case study (Prince William Park)

These presentations highlighted the different outcomes of the three main mapping products, though it also highlighted how they all were representing the gradients in vegetation and ecology in fairly similar ways. The presentation may have given the overall impression that all of the maps are deficient. Only two slides indicated better correspondence among maps at coarser resolution (Macrogroup). However, it is reasonable to conclude that the maps were remarkably different in non-uniform ways at finer resolutions. It should also be noted that some types were remarkably concurrent across mapping efforts even though substantially different methods were used. Focusing in on a particular site, Prince William Park, was also enlightening in that reasons for some differences could be explained by slight differences in the interpretation across moisture gradients and the distribution of types at the ecoregion scale, and increased use of ruderal types by one method (LANDFIRE) over others. This suggests that, while the results are undeniably different, the mismatches are often close "misses."

12:00 Lunch On-site

12:30 Presentations by Map Producers (30 minutes each)

- LANDFIRE (Don Long)
- Southeastern Regional GAP Analysis (Alexa McKerrow)
- NatureServe National Map (Pat Comer and Regan Smyth)
- Northeast Terrestrial Habitats (Mark Anderson and Charles Ferree)

These presentations stand on their own – see the PowerPoints.

2:45 Break

3:00 Characteristics of an Improved Product (Directed Discussion)

- Mapping Targets
- Accuracy
- Spatial Resolution

A user commented that the biggest improvement would be to have the composition of the mapped type on the ground match the conceptual description of the type in the literature. The types are not well-defined, and often it is not clear where to assign a given plot based on ground data. Given the broadness of many of the legend element concepts, it currently requires a great many subjective decisions to properly assign a plot to a particular legend element. Others commented that some concepts are overlapping, but there is also an issue of gaps between concepts. The need for tightening of the classification based on the outcomes of mapping was a recurring theme.

More plot sampling on the ground is needed, possibly using VegBank as a source or repository to share data, and using the plot data to tighten the classification and allow for characterization of currently mapped types.

The concept of getting at ecological condition was mentioned (i.e. the level of degradation caused by stressors). This overlaps with concepts related to defining the variation within a mapped type based on ground data. The definition in the literature may not conform to what is found on the ground. Use of vegetation cover and height from LANDFIRE and/or NLCD was mentioned as a possible solution.

The age of the data was mentioned – SEGAP data is now almost 15 years old.

The inability to map some systems was mentioned as an issue: how can we map more systems?

Can there be a formal way to modify maps? Maybe a web tool?

Performing accuracy assessments on these products is difficult to accomplish for many reasons. Cross-validation results from the classification process are commonly reported. "Fuzzy" accuracy assessment methods may help make assessment results more meaningful. Or in lieu of a statistical accuracy assessment, it is critical to do a comprehensive and systematic review of maps by experts, augmented with selected ground sampling in areas not well known. This is more akin to a "validation" process.

3:30 Mechanisms for Production & Future Options

- Partnerships
- Methods
- Use of National Products
- Development of Regional- or State-based Products

A more exhaustive and formal user needs survey might be in order.

The need for a better and more uniform geophysical setting map was mentioned. At a minimum, development of standard sets of ancillary data could lead us towards a standard geophysical setting data layer.

Use of geophysical setting to help inform conservation priority setting in the face of uncertain climate impacts was mentioned (this, insofar as it is unlikely that we will ever know the current conditions beyond a certain level of detail). However, this does not obviate the urgent need to know current conditions better – again, more on-the-ground samples would help, and use of vegetation height and canopy cover might help.

The need for separate efforts to improve wetlands mapping was mentioned (e.g. NWI-style maps).

It was suggested that a set of commonly accepted ranges for types would be useful.

The concept of using different mapping methods in different regions was mentioned. The need is driven by differences in number of available ground plot samples, human disturbance regimes (and hence the ratio of relatively intact versus disturbed communities), and the steepness of environmental gradients (e.g. mountains) in different regions.

The importance of sharing data was again emphasized – especially existing plot sampling data. The difficulty in terms of getting and using FIA data is an issue. Keeping EOR data up to date and adding more samples for both rare and common types is an issue.

5:00 Adjourn
